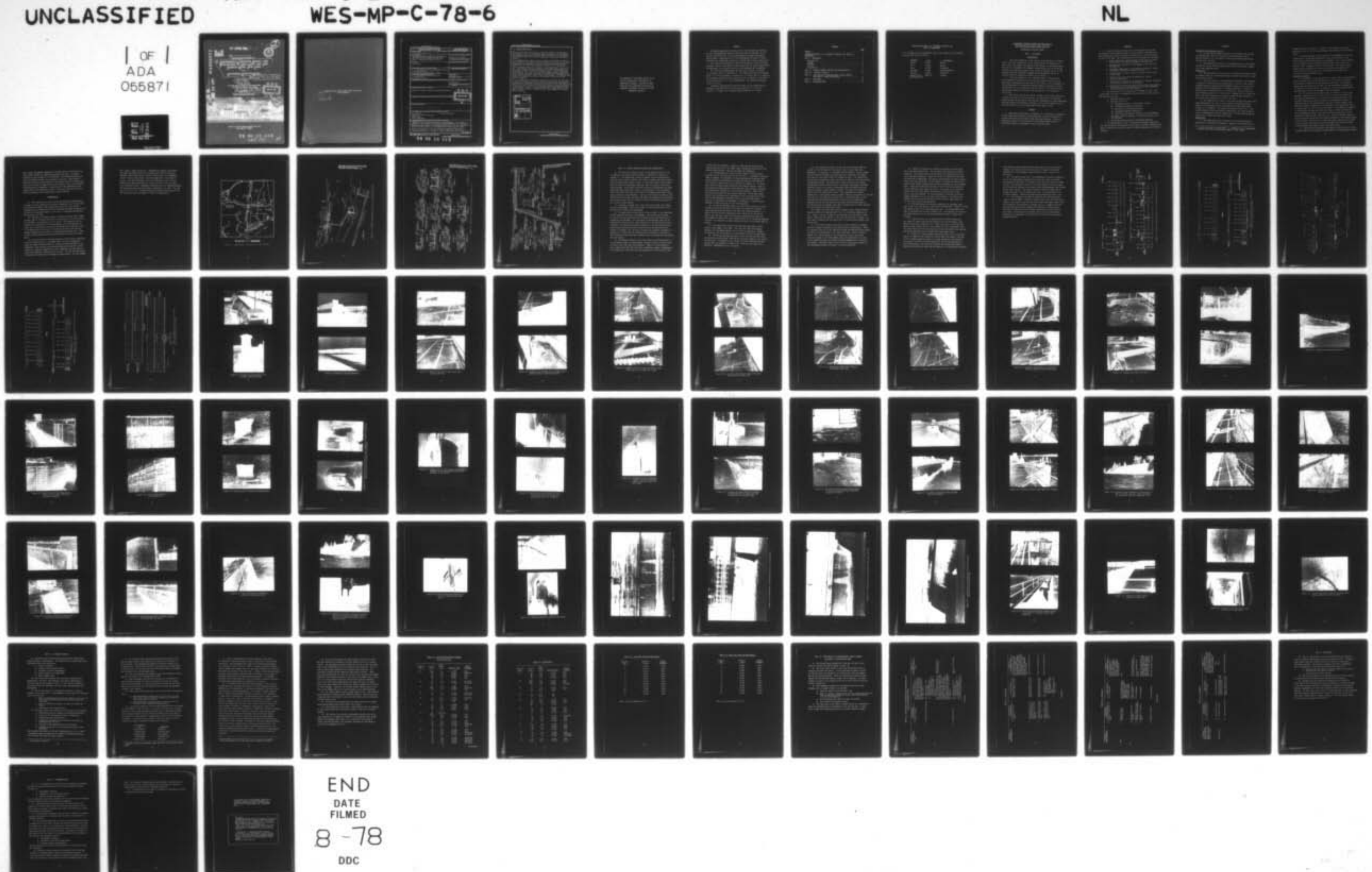
AD-A055 871 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/2
ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DA--ETC(U)
MAY 78 C E PACE

UNCLASSIFIED WES-MP-C-78-6 NL

| OF |
ADA
055871



END
DATE
FILMED
8-78
DDC

AD A055871

AD No.
DDC FILE COPY

B.S. 2

FOR FURTHER TRAN II

9 MISCELLANEOUS PAPER C-78-6

6 # ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DAM HUDSON RIVER, NEW YORK.

Report 1.

ENGINEERING CONDITION SURVEY.

NH

by

10 Carl E. Pace

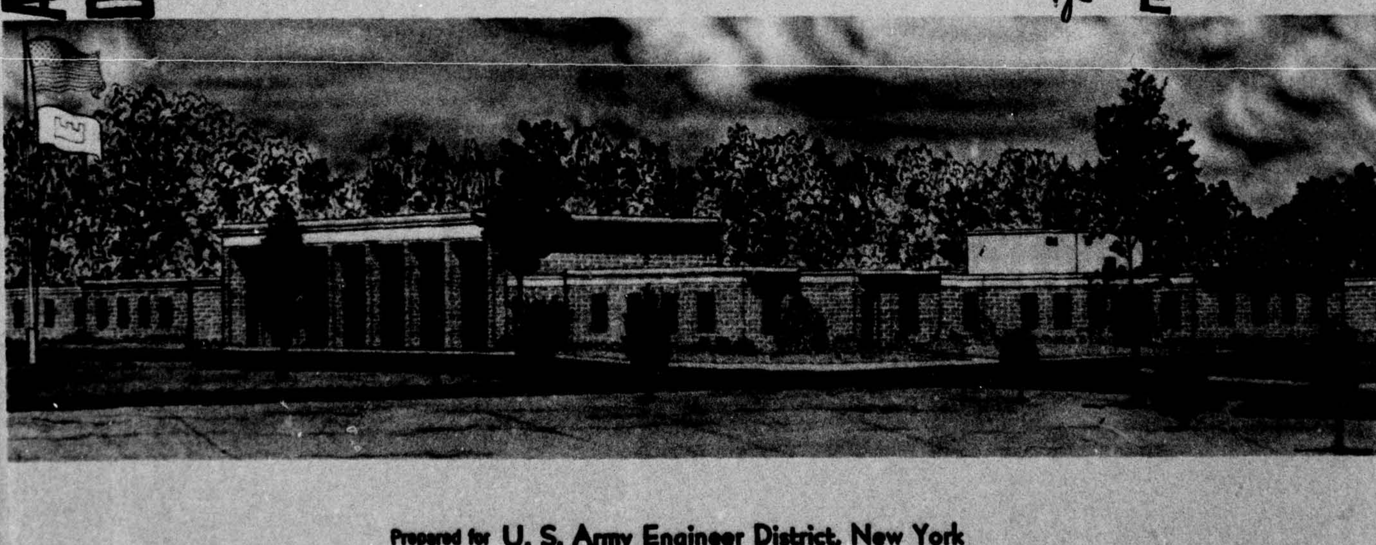
24 WES-MP-C-78-6

Concrete Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

11 May 1978

12 84 p.

Report 1 of a Series



Prepared for U. S. Army Engineer District, New York
New York, N. Y. 10007

Destroy this report when no longer needed. Do not return it to the originator.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Miscellaneous Paper C-78-6	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DAM, HUDSON RIVER, NEW YORK; Report 1, Engineering Condition Survey		5. TYPE OF REPORT & PERIOD COVERED Report 1 of a series 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Carl E. Pace		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Concrete Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, New York 26 Federal Plaza New York, N. Y. 10007		12. REPORT DATE May 1978 13. NUMBER OF PAGES 80
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

In Phase I of this study, a

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam stability
Engineering condition surveys
Hudson River
Locks (Waterways)
Troy Lock and Dam

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A condition survey was made of Troy Lock and Dam (Phase I of the study). An analysis of the condition survey gives adequate information for sound engineering decisions needed for developing a proposal for the total evaluation of the lock and dam, which is to be accomplished in Phase II of the study.

Initial observations of Troy Lock and Dam gave misleading impressions of structural deficiencies. The Phase I study revealed that the interior

(Continued)

78 06 19 015

20. ABSTRACT (Continued).

concrete of the lock is sound and of sufficient strength. The cracking of the concrete in the lock is negligible and is insignificant in the dam and gated spillway except for (a) the pier where the access to the dam tunnel on the powerhouse side of the river is located and (b) the piers of the gated section.

It is recommended that concrete cores be obtained to determine the depth of deterioration of the surface concrete and typical cores be used for (a) petrographic analysis, examination for deteriorating agents, material property determination, and evaluating dam monolith contact with the foundation.

Stability analyses should be performed on selected monoliths of the lock and dam. Stress analyses should be performed on the badly cracked monolith of the dam that contains the shaft which allows access to the dam tunnel from the powerhouse side of the river, and stress analyses should be performed on one monolith of the dam to determine the effects of water-produced vibrations. Specific methods of repair should be recommended. A feasibility study should then be made and the repair or replacement of Troy Lock and Dam should be suggested.

If it is assumed that the structural evaluations in the Phase II study reveal no serious deficiencies and that the concrete cracking in the dam and gated spillway can be effectively repaired and preventative measures implemented, the lock, dam, and gated spillway are structurally adequate and can be repaired. At this stage of the study, all conditions have not been evaluated such that the feasibility of repair is certain, but the Phase I study indicates that repair is highly feasible if the deficiencies listed ~~herein~~ can be economically corrected.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

PREFACE

The engineering condition survey of Troy Lock and Dam was conducted for the US Army Engineer District, New York, Corps of Engineers, by the Concrete Laboratory (CL) of the US Army Engineer Waterways Experiment Station (WES). Authorization for this investigation was given in intra-Army Order for reimbursable services No. NYD-76-104(c) dated 19 March 1976.

The contract was monitored by the New York District Office with main assistance from Mr. Tony Barbero, whose cooperation was greatly appreciated. The assistance of Mr. Roselle and other lock personnel was outstanding.

The study was performed under the direction of Messrs. B. Mather, J. M. Scanlon, and J. E. McDonald, CL. The condition survey was performed by Dr. C. E. Pace and Messrs. H. Thornton, E. F. O'Neil, and J. T. Peatross. The ultrasonic work and write-up was done by Mr. H. Thornton. The review of the report by Dr. T. C. Liu is appreciated. The report was prepared by Dr. C. E. Pace.

Commanders and Directors during the conduct of the program and the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	0.0254	metres
feet	0.3048	metres
miles	1.6093	kilometres
feet/mile	0.1893	metres/kilometre
feet/sec	0.3048	metres/sec
pounds (force) per square inch	6894.757	pascals

ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DAM, HUDSON RIVER, NEW YORK

ENGINEERING CONDITION SURVEY

PART I: BACKGROUND

Introduction

1. Troy Lock and Dam is a vital link in the navigation on the Hudson River. The lock is essential for the transportation of commodities by tugs, tows, tank barges, self-propelled tank barges, and dry-cargo barges. Not only is it essential for commodity transportation, but it has become the means by which many pleasure craft travel up and down the river. The pleasure craft has increased in number as time has passed, and it is expected that this trend will continue in the future.

2. Troy Lock and Dam is in an advanced stage of deterioration and a systematic evaluation of its structural integrity as well as the maintenance requirements are important at this time. In all likelihood, if this consideration is not made and remedial measures performed, the lock and dam will have to be replaced in the near future. It is believed that restoration procedures can save the lock and dam for 30 to 50 years of future life.

3. This report presents the results of Phase I work which consists of a condition survey of Troy Lock and Dam. The analysis of the condition survey as given in this report gives adequate information for good engineering decisions needed for developing a proposal for the total evaluation of the Lock and Dam which is to be accomplished in the Phase II work.

Purpose

4. This study (consisting of two phases) is to establish the condition of the deteriorated structure and determine what action is necessary to feasibly keep this lock and dam in good operating condition. Since the construction costs of a new structure of this nature would be 150 to 200 million dollars, the endeavor is well worth the effort.

Approach

5. A detailed condition survey of the lock and dam will be made. The analysis of the condition survey will give adequate information for good engineering decisions to develop a proposal for a total evaluation of the lock and dam. The condition survey will accomplish the following:

   a. Cracks mapped onto scaled drawings of the concrete surface of the lock and of tunnels in both the lock and dam.

   b. Determine any settlement or misalignment of the lock and dam monolith.

   c. Ultrasonic investigation to determine the extent of cracks and general condition of interior concrete.

   d. A correlation of surface cracks to interior tunnel cracks for the lock.

   e. Testing of the water from the Hudson River for any deteriorating effects.

   f. Nondestructive testing of the concrete for quality, especially in critically stressed or cracked areas.

   g. Preparation of plans for a detailed structural investigation which will lead to recommendation for corrective measures of deficiencies at Troy Lock and Dam.

6. The final part of the evaluation will be Phase II work. This second phase will lead to recommended remedial measures for the lock and dam which will involve:

   a. Obtaining concrete cores.

   b. Using the cores for:

      (1) Determining extent of deteriorated concrete.

      (2) Performing petrographic analysis.

      (3) Examining for deteriorating agents.

      (4) Determining material properties.

      (5) Evaluating dam monolith contact with the foundation.

   c. Performing stability analysis of typical monoliths of the lock and dam.

   d. Performing stress analysis of distressed monoliths.

7. It was necessary to have a detailed and systematic analysis of the lock and dam as is presented in this report to provide information for Phase II work and to develop a basis for further planning and structural analysis.

Location

Geographic and navigation location

8. The Troy Lock and Dam, also known as the Federal Lock and Dam, is geographically located in the City of Troy, Rensselaer County, New York (Figure 1.1), 152.5 miles* north along the Hudson River from New York City, New York.

9. The navigational location is on the Hudson River at the eastern terminus of the New York State Barge Canal and at the southern terminus of the Lake Champlain Canal.

Hudson River

10. The Hudson River has its source in central New York State among the highest peaks of the Adirondack range near Mount Marcy (5344 ft above mean sea level (msl)).

11. From this source, it flows generally southeast to Fort Edwards, a distance of 120 miles with an average fall of 43 ft per mile, thence southward through a canalized reach (Champlain Canal) to its junction at Waterford with the Mohawk River, its largest tributary, a distance of 39 miles with an average fall of 3.3 ft per mile, thence to the Troy Lock and Dam a distance of 2.4 miles with an average fall of 0.013 ft per mile, and thence southward to its mouth in New York Bay a distance of 152.5 miles, an average fall of 0.013 ft per mile.

12. The Hudson River is tidal to Troy Lock and Dam with a mean tidal range downstream of the lock of 4.8 ft during the navigation season, which has an average duration of approximately 250 days (from about 31 March to 15 December). The spring tidal range is about 5 ft. Variations recorded in the water surface elevations in the tidal section of the river downstream of the dam ranged from 3.5 ft below msl during low flows to 29 ft above msl during flood flows.

Mohawk River

13. The Mohawk River from its source to its junction with the Hudson River flows generally eastward, a distance of 155 miles with an

---

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4 of this report.

average fall of 6 ft per mile. For most of this distance it has been canalized as part of the Great Lakes-Hudson River Waterway (New York Barge Canal).

14. Although the main junction channel of the Mohawk River with the Hudson River is at Waterford (upstream of Troy Lock and Dam), it has several branch channels which also join the Hudson. One of these branches, the fifth branch, enters the Hudson River from the west of Troy, only about 0.5 mile upstream of the Troy Lock and Dam. Flow from the fifth branch varies generally with the flow in the Hudson, averaging around 10 percent of the total flow at the dam during low flows and about 21 percent during the higher flows.

Geological location

15. Geologically, Troy Lock and Dam is located within a sub-triangular inner lowland in east central New York State. The region is enclosed by the mountain ranges of the Adirondacks on the north, the Rensselaer Plateau and the Taconics on the east, and the Helderberg escarpment and the Catskills on the southwest. A great part of the surrounding mountain area slopes and directs its drainage toward the lowland.

16. The east side of the Hudson River is flanked by a belt of predominantly shale-type rocks. In the vicinity of the lock and dam this belt extends approximately 6 to 8 miles in an east-west direction. The principal formations include the Snake Hill and Normanskill shales of Ordovician Age and the Schodach shale and stone of lower Cambrian time. The lock and dam is underlain by the Normanskill black argillaceous shale at depths from 25 to 28.5 ft below the surface. The Normanskill formation is interrelated with many grit and chert beds, the whole of which have been compressed into folds. The rock is further characterized by the presence of numerous shear zones and joint. Fracture cleavage, whereby the rock has been parted into thin plates independent of the bedding planes, is also evident. Outcrops of the Snake Hill shale formation can be found in the City of Troy as well as across the Hudson River along the shores of Green Island, Van Schaick Island, and Peobles Island.

17. The natural soil materials overlying the bedrock in the vicinity consist primarily of Pleistocene outwash deposits. These materials include

silts, sands, and gravels deposited by the melt waters of the glacial ice sheets which invaded the region during Pleistocene time. Occasional boulders are also included in the overburden. The outwash materials have filled the valleys of many of the streams of the area. Some alluvial deposits, derived from the reworking of the glacial soils by stream action, have been laid down in comparatively recent times on top of the unconsolidated Pleistocene foundations. A great deal of these deposits has been brought down by the Hudson River and its tributaries from above Troy and filled the channel of the Hudson River in many locations.

Construction

18. The construction of Troy Lock and Dam (presented schematically in Figure 1.2) was authorized by the River and Harbor Act of 25 June 1910. An extension was added to the existing guide wall and a new concrete bulkhead wall was constructed in 1961 to eliminate hazardous navigation conditions at the upstream entrance to the lock. A downstream mooring wall was constructed in 1969.

19. The dam is a concrete gravity, overflow structure with a length of about 1300 ft, of which 586 ft has a top elevation of 14.33 ft msl and the remainder a top elevation of 16.33 ft msl. The navigation lock is located at the eastern end of the dam adjacent to the east bank of the river, and a power plant is located at the western end of the dam. Also on the western end of the dam is a 25-ft-wide ice pass, which has the machinery removed and acts only as a noncontrolled overflow weir. There is also a 195-ft-long gated section which serves the flume to the power plant.

20. The low section of the dam (elevation 14.33 ft msl) is adjacent to the lock and its crest is provided with 2- by 16-ft flashboards, which are raised during low flows to increase the head available at the powerhouse. They are held in the raised positions by pins that are designed to be sheared automatically so the flashboards collapse when the upper pool reaches an elevation of 18.5 ft msl. The lock was constructed of concrete on bedrock and is equipped with miter gates. The lock chamber

has a usable length of 492.5 ft. Originally the chamber was divided into upper and lower units; but the middle gates have all operating machinery removed and are left in place only to serve as an emergency closure if such a need arises. The lock chamber has a clear width of 44.4 ft. The upper miter-gate sill is at elevation -2 msl, the lock chamber has a bottom elevation of -16 msl; the tops of the lock walls are at elevation 24 msl. Navigation through the lock is suspended whenever the water level above the dam exceeds an elevation of 21.5 msl. The lock has a lift of 17.3 ft. Sections showing the general construction of the lock and dam are given in Figures 1.3 and 1.4, respectively.

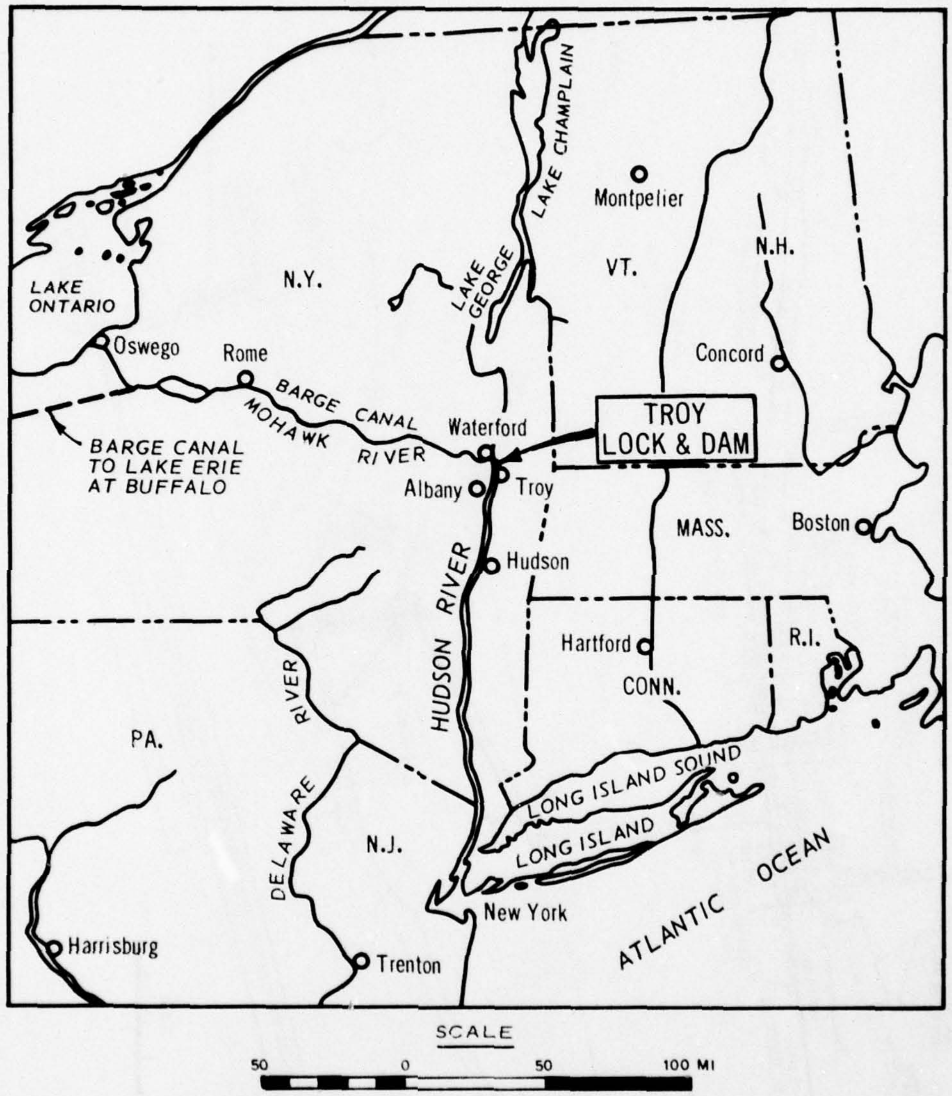


Figure 1.1 Geographical location of Troy Lock and Dam.

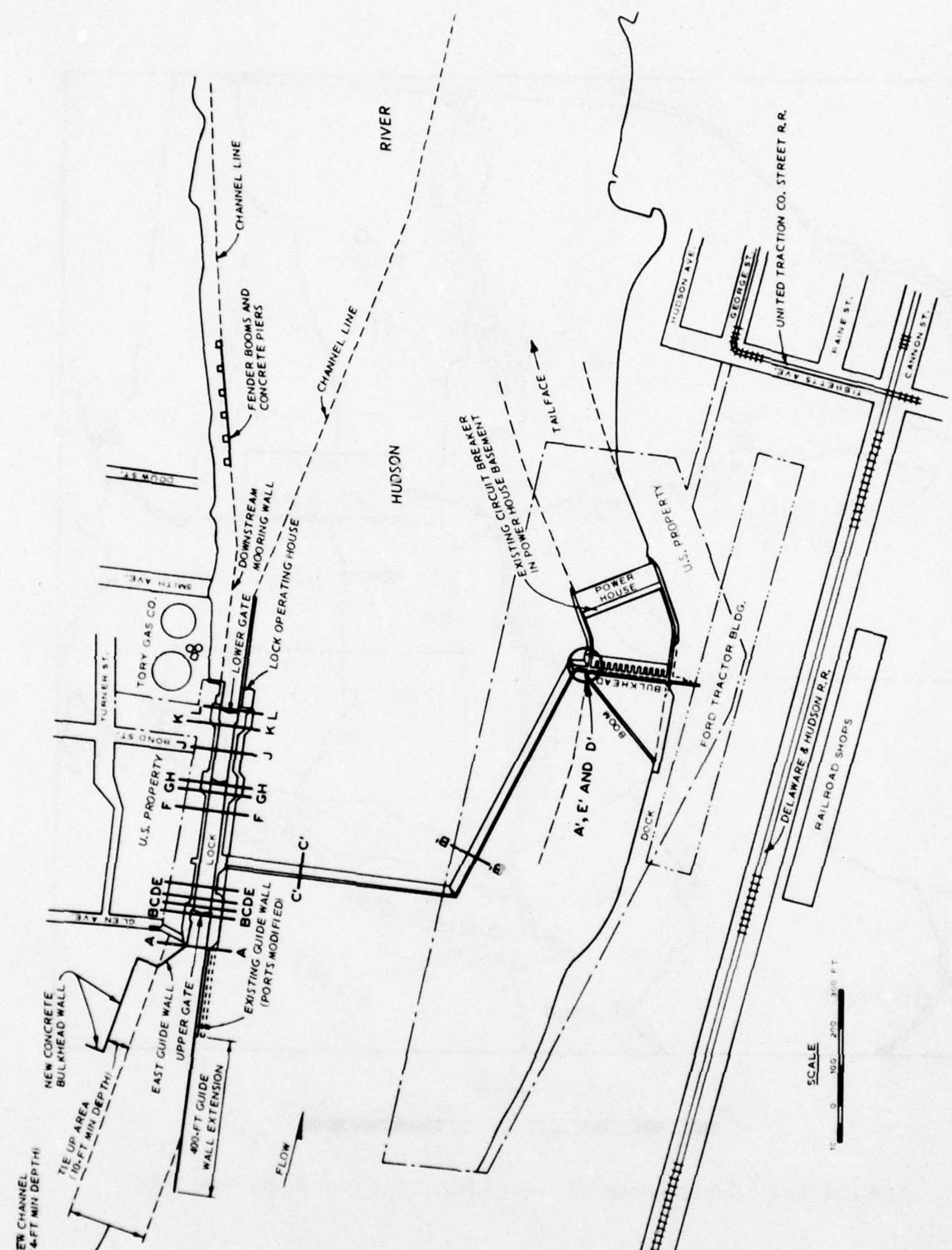


Figure 1.2 Schematic presentation of lock, dam, and power plant.

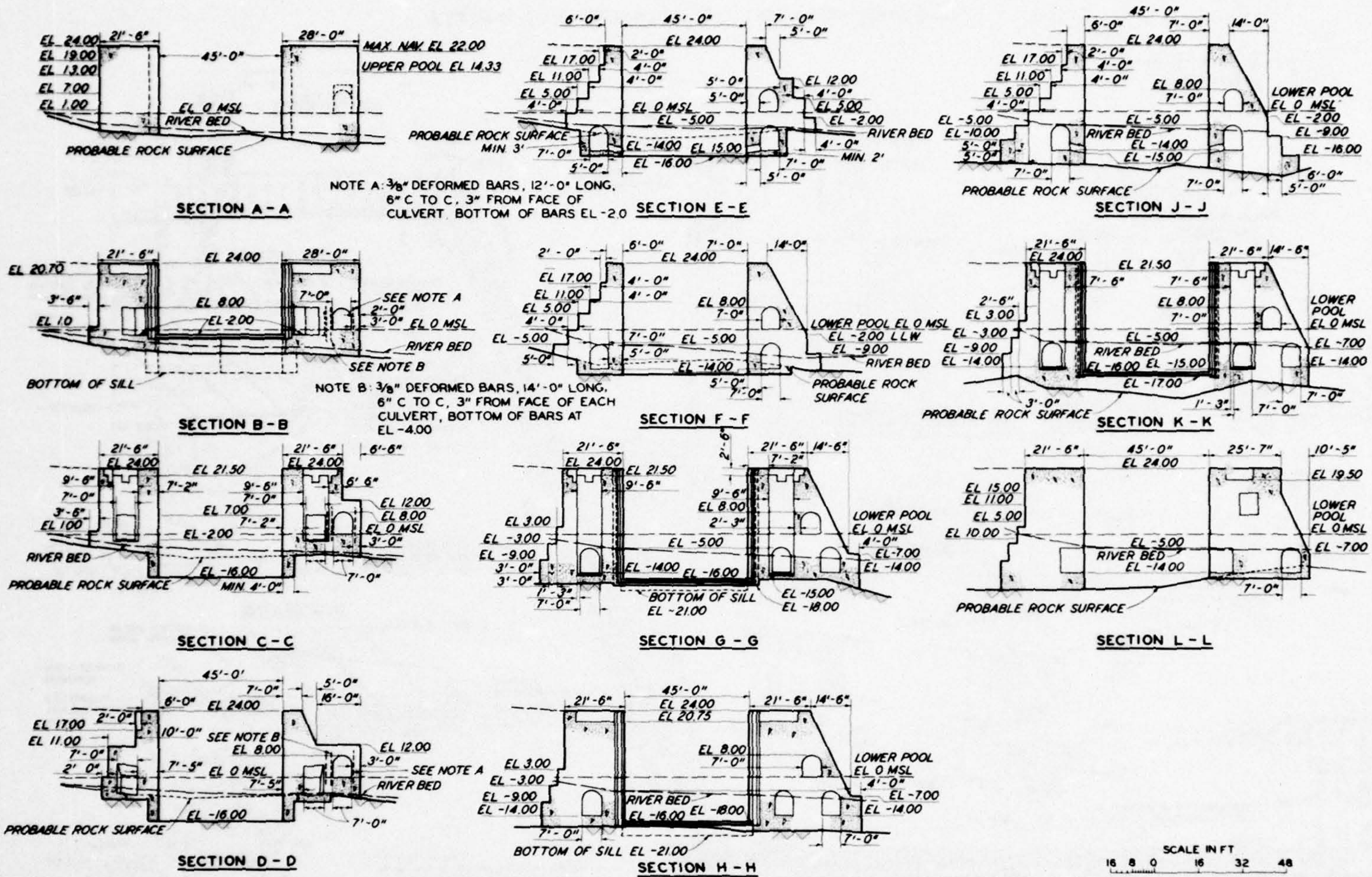


Figure 1.3 Sections through lock as indicated in Figure 1.2.

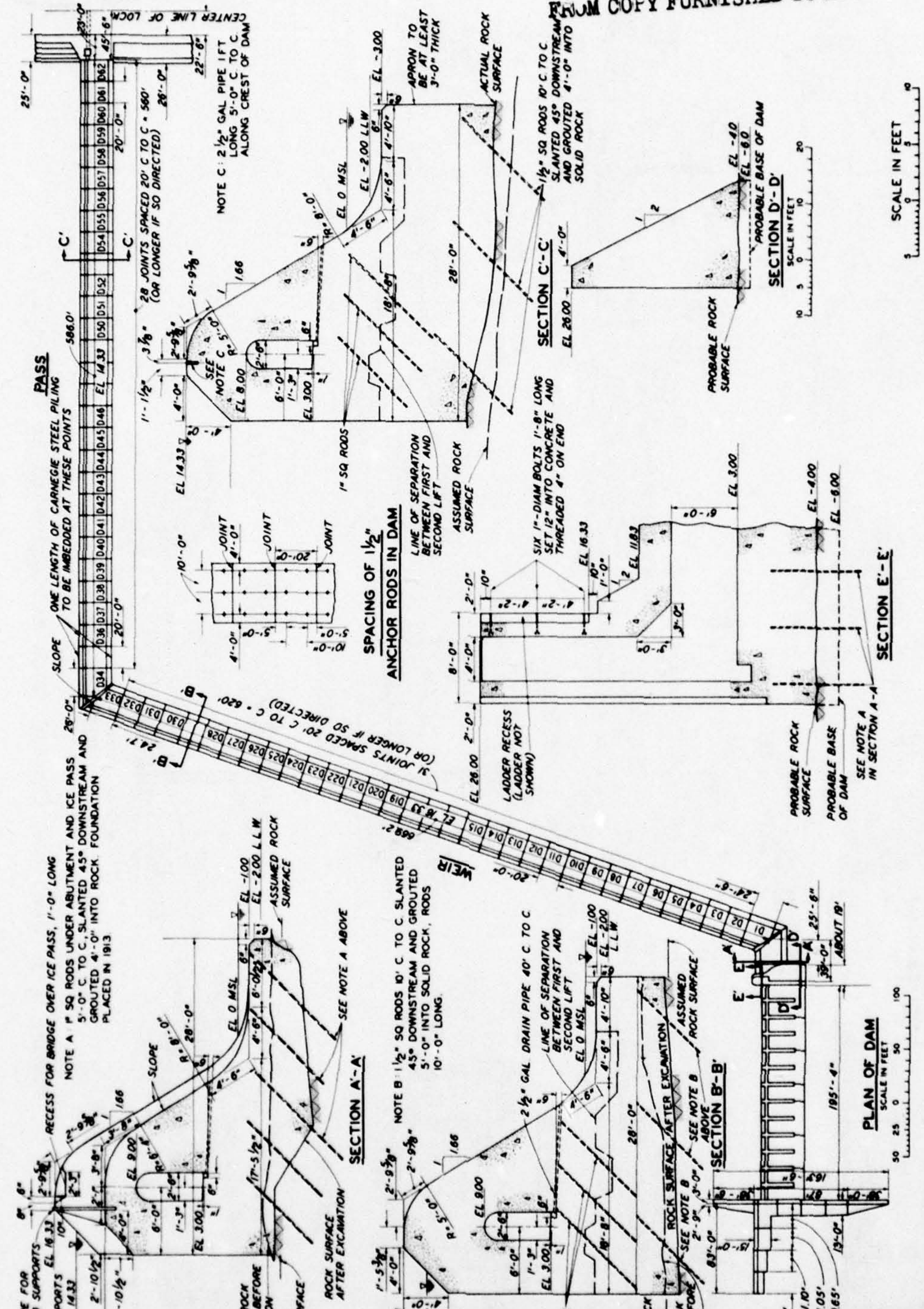


Figure 1.4 Details of dam construction.

PART II: SURFACE CONCRETE CRACKING AND DETERIORATION

21. The concrete cracking, as seen on the exposed surfaces of the lock walls, lock tunnels, and dam tunnel, is indicated in Figures 2.1 through 2.5. The significant cracks are mapped onto plan and elevation views in order to better present their extent in number and their location. The term "significant cracks" refers to cracks that appear to have some depth; it does not necesssarily mean that they are going to cause structural problems. Cracks which could have structural significance are those within the shaft which allow access to the dam tunnel on the powerhouse side of the river and those in the piers of the gated section which allow access of water to the powerhouse. There are relatively few cracks in this 58-year-old lock and dam, and they have their main significance in allowing the access of water into the concrete, thereby accelerating deterioration due to freezing and thawing.

22. Spalling, leaching, and in some cases even cracks can be shown better by photographs. With this in mind, the deteriorated surface condition will be presented by photographs.

23. The gated section which allows access of water to the powerhouse is best presented entirely by photographs. The spalling and leaching on the lock and dam surfaces are not indicated on the plan sheets but are presented by photographs. The area which the photographs cover will be representative and will give a good indication of the deteriorated surface condition. The deteriorated surface condition of the lock walls and the deteriorated construction joints of both the lock and dam are given in Figures 2.6 through 2.45, and their locations are indicated in Figures 2.1 through 2.5 in order that the conditions can be reviewed in relation to their location, thereby getting a sequence and total perspective concerning the lock and dam.

24. The surface condition of the lock, dam, and spillway section is in the advanced stage of deterioration. Figures 2.6 and 2.7 give an overall view of the lock, dam, and powerhouse. Figure 2.6 (from bottom to top of page) views the lower miter gate, powerhouse, general configuration of the land wall, river wall, and the beginning of the dam from the lock

as seen from the powerhouse. Figure 2.7 (bottom view) shows the dam starting from the lock at the upper right, bending and projecting to the gated spillway section. The top view shows the powerhouse.

25. The deterioration of the concrete surface of the land wall monoliths is not as bad as that of the river wall. A sequence of pictures shown in Figures 2.8 through 2.16 starts upstream and progresses downstream showing the deteriorated top concrete surface of the land wall. The location of these views is also presented in Figure 2.1. As can be seen, there is spalling and cracking of the concrete surface. Most of the surface has been patched or overlayed with newer concrete; therefore, the spalling and cracking are of the concrete overlays. These cracks may or may not extend into the original monolith. As has been stated earlier, the cracking is not significant in the top surface of the land wall and the deteriorated concrete surface just needs maintenance. There is no indication of misalignment, settlement, or critical stress problems in either the land or river wall monoliths.

26. As will be discussed later, the construction joints are a major problem at this lock and dam and will have to be sealed to alleviate future deterioration and, hence, structural and operating problems. In Figure 2.10 the vertical construction joint (which can be seen at the back of the lock wall, upper view) has water gushing from it when the lock chamber is almost full due to pressure head in the filling and emptying culverts. This signifies an open construction joint or crack which must be sealed.

27. The construction joints of the land wall monoliths, as seen from the lock chamber, look tight. The lock walls show some gouging (Figure 2.19) from barge impact, but it is not too extensive. Besides the abrasion, the lock walls are of sound concrete and are in good shape.

28. The filling and emptying ports in both the land and river walls are deteriorated (see Figure 2.20) and are in need of repair at the face of the lock wall. The majority of the ports are in this condition and only typical ones are presented in Figure 2.20. Each port will need to be evaluated independently as it is repaired.

29. The construction joints, as seen in the filling and emptying tunnels of both the land and river walls, leak; in fact, some leak extensively. In general, it is assumed that the amount of frozen seepage from the backfill through the construction joint represents the degree the joints are open which allows the seepage of water. All construction joints allow the passage of water into both the land and river wall filling and emptying tunnels. The construction joints as seen in the filling and emptying culverts should all have a consistent maintenance treatment; therefore, there is no reason to distinguish some as needing repair and others as needing a lesser degree of repair. The same action should be taken for all the construction joints. Some representative seepage forming ice at construction joints is shown in Figures 2.21 and 2.22 for the land wall and river wall monoliths, respectively. The deterioration at the construction joints which allows water to flow into the filling and emptying culverts will accelerate as the water freezes within them; as the water freezes and expands, many small fractures will be caused throughout the area near the construction joint.

30. Figure 2.23 (top view) shows a stream of water flowing from the saturated backfill through monolith 5 into the filling and emptying culvert. This, as well as seepage of water through the lock walls at other places, shows that the concrete in the land wall monoliths is porous. In fact, mud is seeping from the culvert wall in certain places (Figure 2.23, bottom view).

31. In all mass concrete structures the main location of cracking occurs at changes in geometry which causes stress concentrations. There is cracking in the top of the land wall filling and emptying culverts where it turns to exit downstream of the lower miter gate. This is shown in Figure 2.24. This cracking is not structurally critical and should cause no problems if the lock chamber walls are sealed and/or the lock is not dewatered during cold weather allowing seepage water to freeze in the opening. Freezing of water in the crack can cause deterioration of the surrounding concrete thus deteriorating the monoliths.

32. Figure 2.25 (bottom) is viewing the original and newer guide wall in an upstream direction. The new guide wall extension is in good condition. The original guide wall has bad surface deterioration but it is not cracked extensively. Figure 2.25 (top) is viewing the river wall from upstream to downstream. The surface deterioration is severe and there needs to be some maintenance of this surface to prolong the life of this lock and dam, thereby moving toward economy in navigation along the Hudson River. Figure 2.26 shows deterioration in front of the first operation station upstream of the upper miter gate. To the side of the operation station we see the lock surface toward where the dam joins the lock wall; it has been repaired. At the intersection of the dam to the lock (Figure 2.28), there is a lot of surface deterioration. In Figures 2.29 through 2.32 we see further down the lock on the river side; there is a lot of surface concrete deterioration.

33. The deterioration of the upper guide wall is consistent with that of the river wall and is in great need of maintenance. Figure 2.33 shows the downstream end of the downstream guide wall. The deteriorated river side of the guide wall is seen in Figure 2.34. The reduction in section of the supporting walls of the operating building is shown in Figure 2.35 (bottom).

34. There is also a lot of undercutting or section reduction at the region of normal tidal fluxion (Figure 2.35 (top) and Figure 2.36). There is also water flowing out of a construction joint in the lock wall from the power tunnel into the river (Figure 2.35 (top) and Figure 2.36). The power tunnel could not be inspected, but dye was placed in its upstream end and was observed to flow through this construction joint.

35. Figure 2.37 shows leaking construction joints in the dam tunnel. Figure 2.5 indicates the construction joints which are leaking. The dam is not cracked severely but there is a heavy vibration of the dam monoliths due to the force of water flowing over its top and downstream to the stilling basin. The vibration frequency and displacement should be monitored and applied as input and the response of a dam monolith evaluated.

Even though the dam has functioned for many years, it has deteriorated (Figures 2.38 through 2.41) and could now be in danger of structural problems due to the tremendous vibrating water force to which it is subjected.

36. The gated section next to the powerhouse has surface deterioration of the same degree as experienced on the river wall of the lock. The cracking in the piers of the gated section does have structural implications. The cracking in the top of the piers (Figure 2.42) was caused by ice and debris lodging on the handrail and inducing moments and stresses beyond their capacity. The handrail should be light in weight and removable such that it can be removed when there is a possibility of ice or debris lodging. Leaching from these piers is presented in Figure 2.43.

37. The cracking in the shaft located near the powerhouse which leads to the dam tunnel is extensive (Figure 2.44), and the construction joints in this shaft are so bad that water gushes from them (Figure 2.45). The cracking in this monolith is probably due to ice lodging on the weir and gated spillway sections inducing overstressing in this monolith. *This cause is indicated* by the relative dislocation at either side of the cracks. The monolith at this shaft should be cored and analyzed structurally to determine the significance of the cracks and necessary remedial measures.

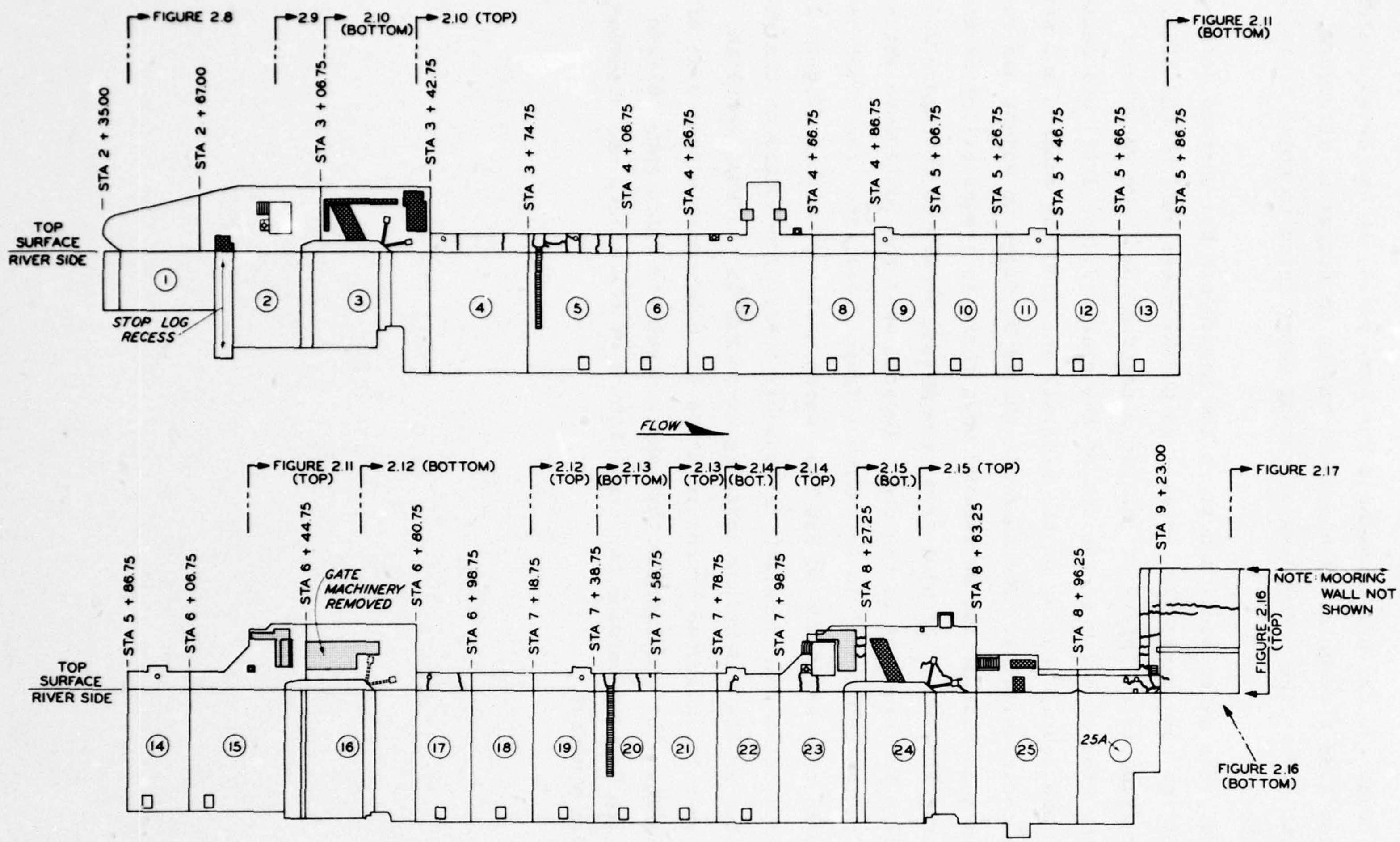


Figure 2.1 Surface cracks, landwall, Troy Lock and Dam, Troy, New York.

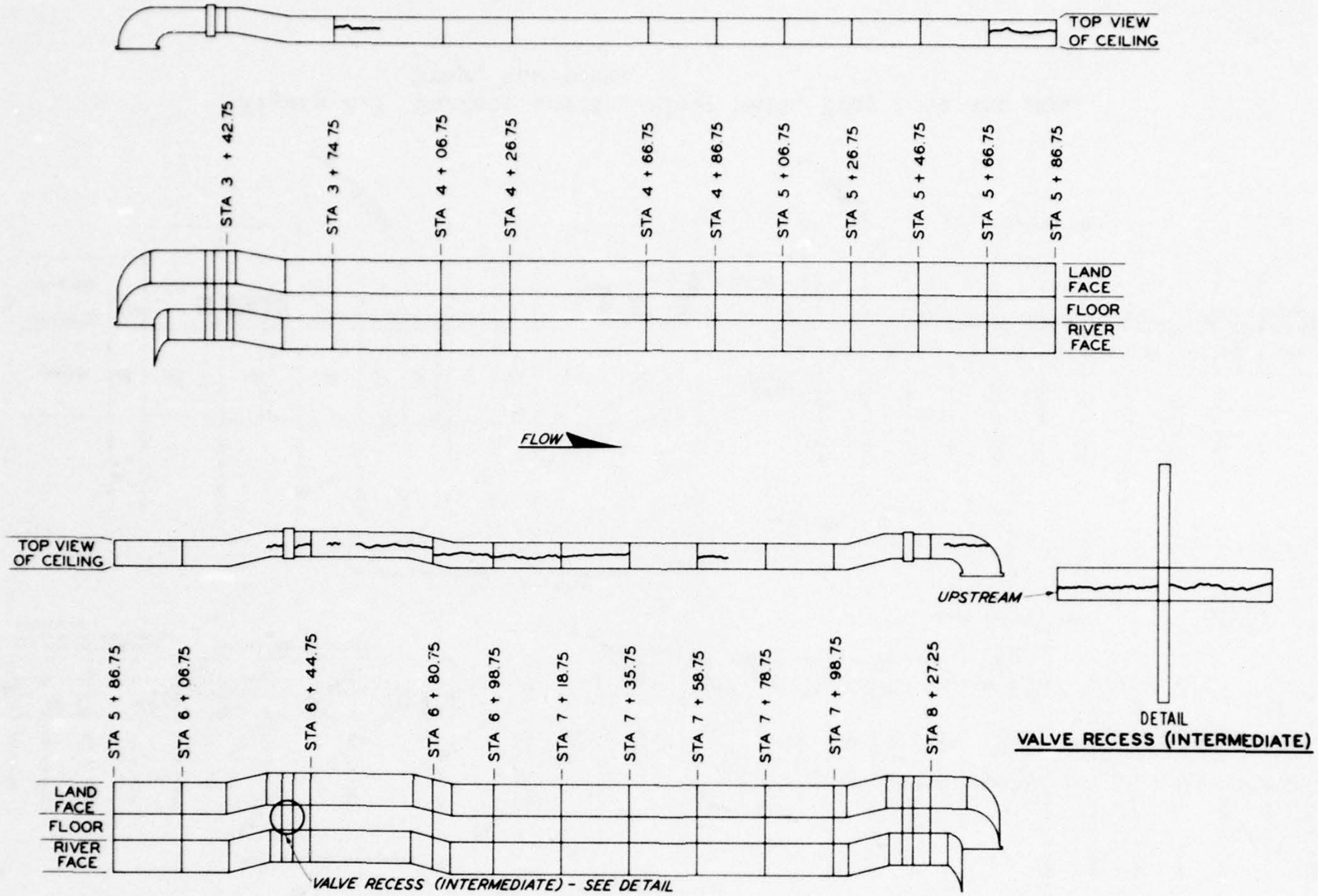


Figure 2.2 Surface cracks, landwall filling and emptying culvert, Troy Lock and Dam, Troy, New York.

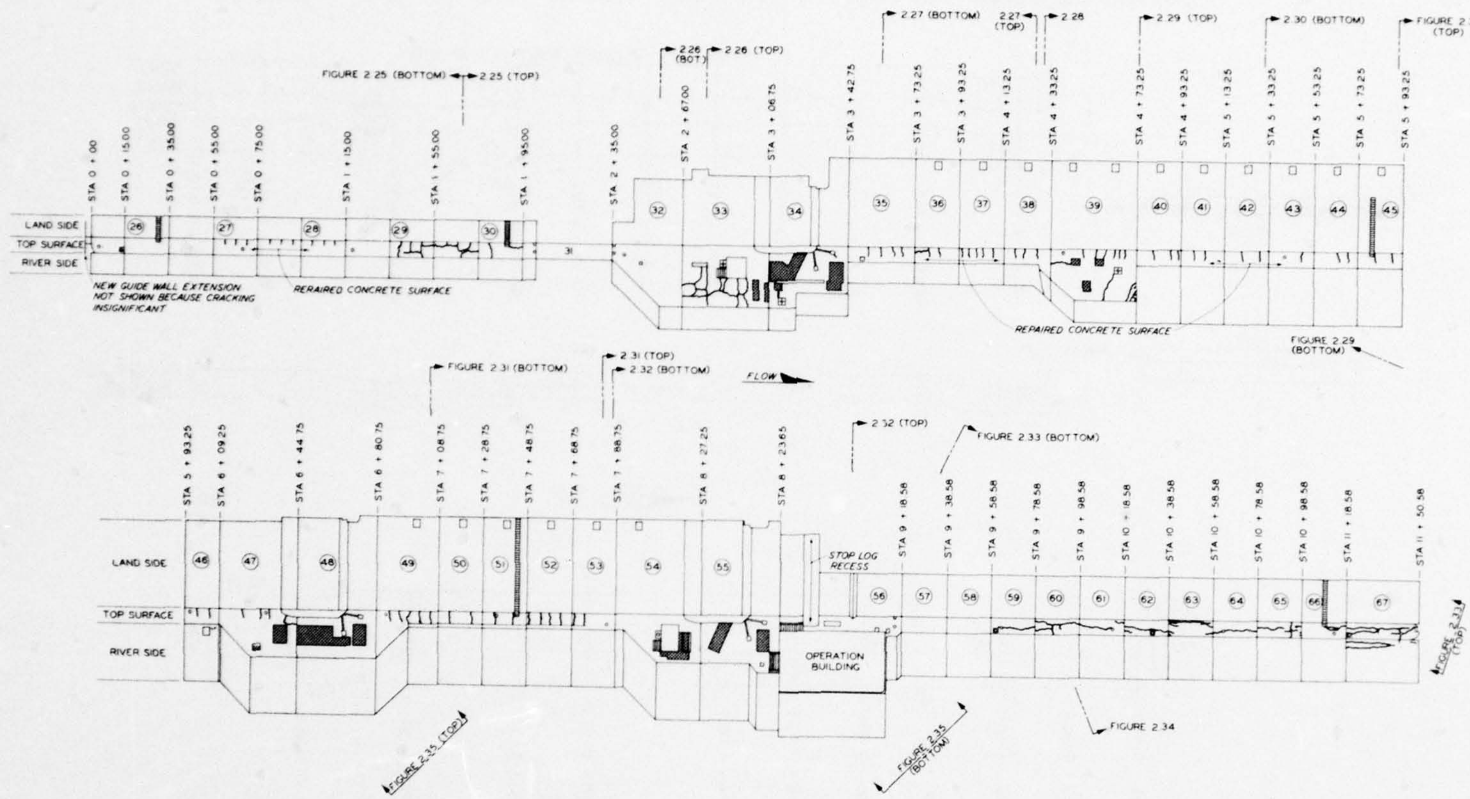


Figure 2.3 Surface cracks, river wall, Troy Lock and Dam, Troy, New York.

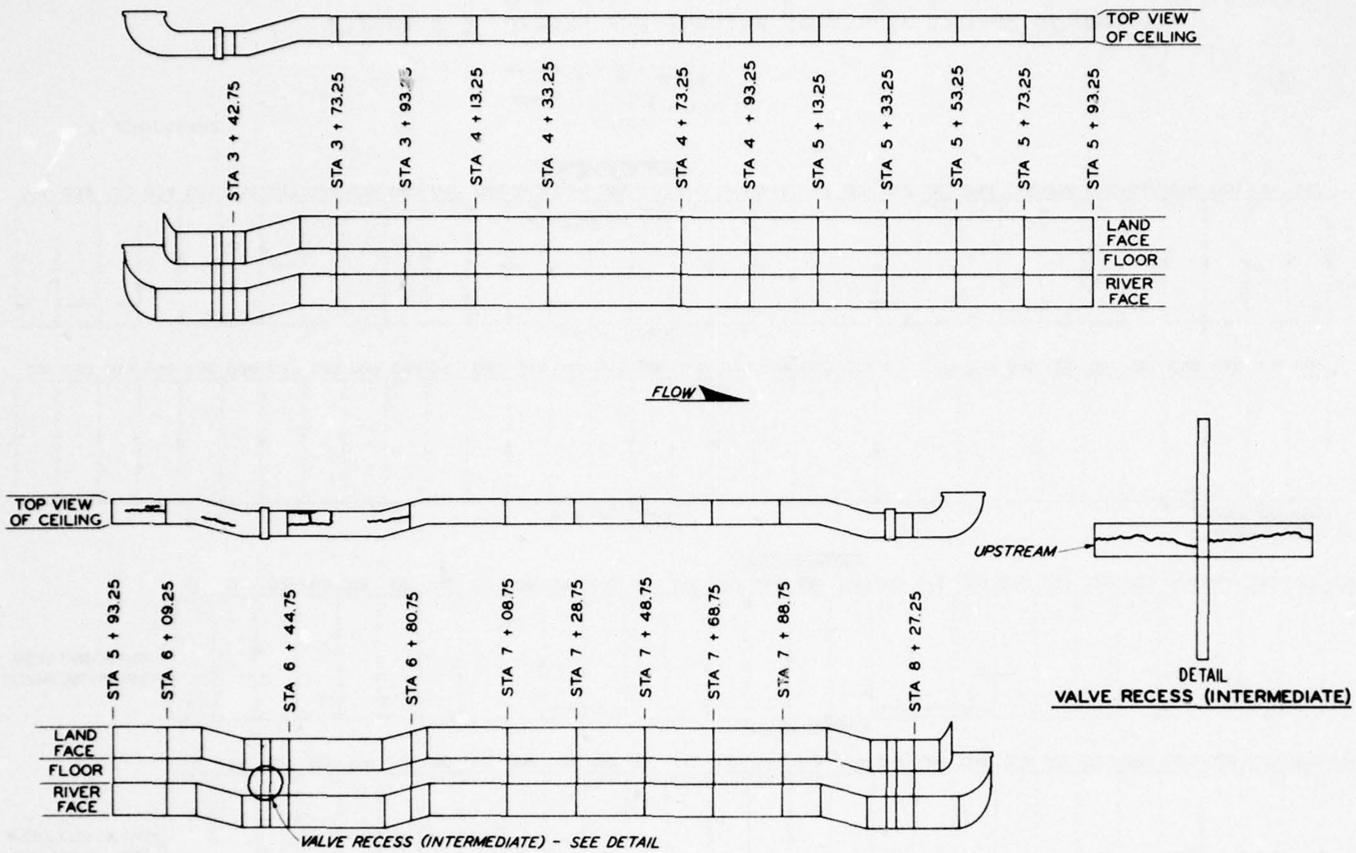


Figure 2.4 Surface cracks, river wall supply tunnel, Troy Lock and Dam, Troy, New York.

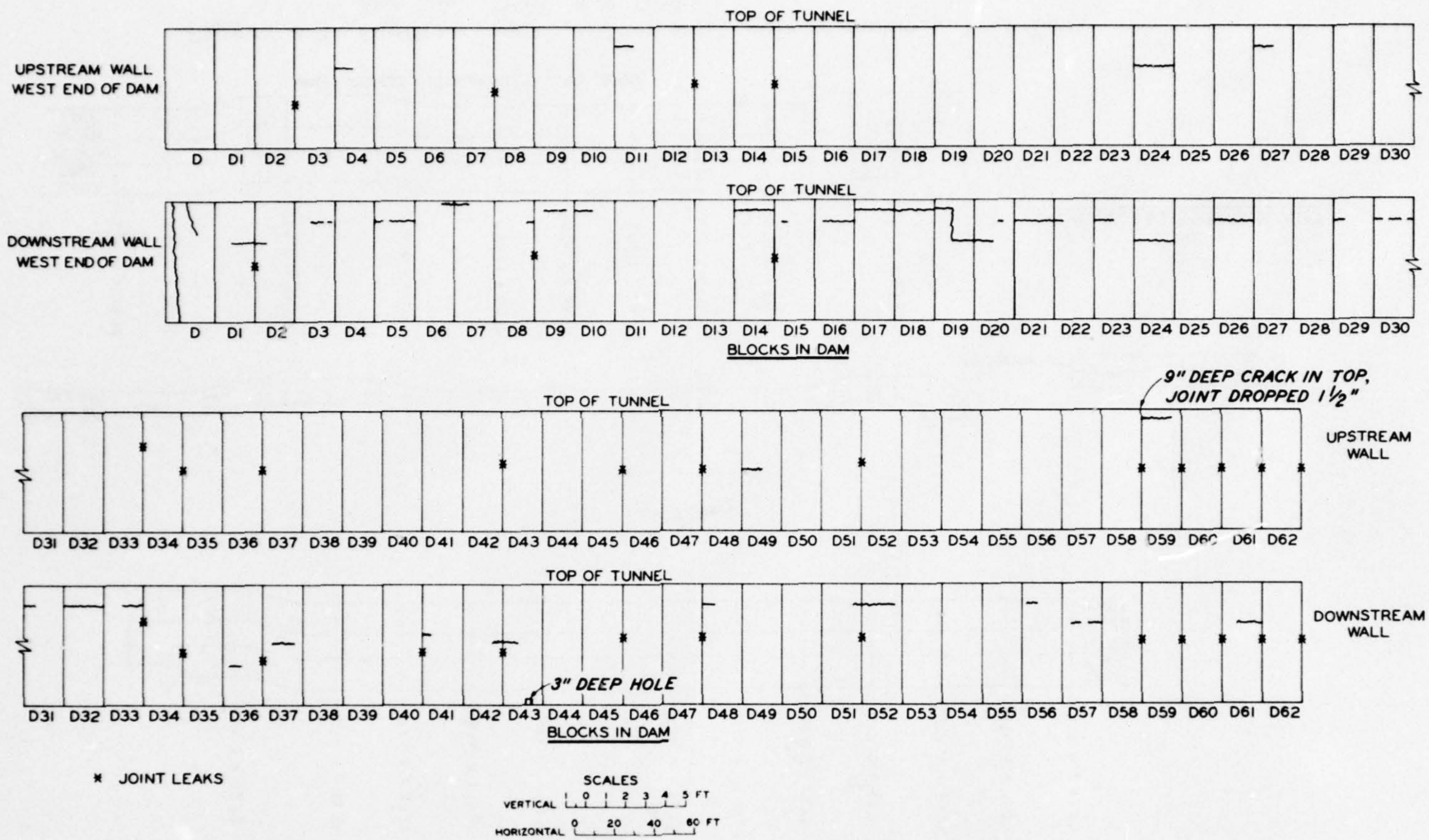


Figure 2.5 Cracks and leaking joints in tunnel of dam, Troy Lock and Dam, Troy, New York.

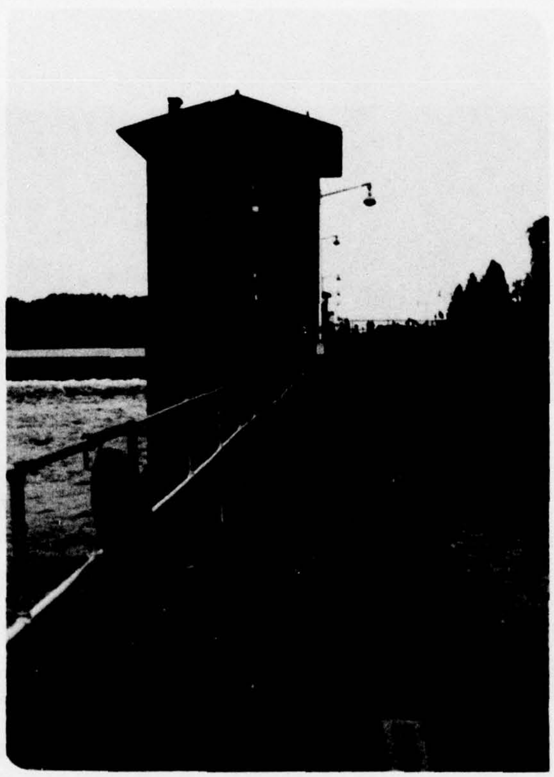
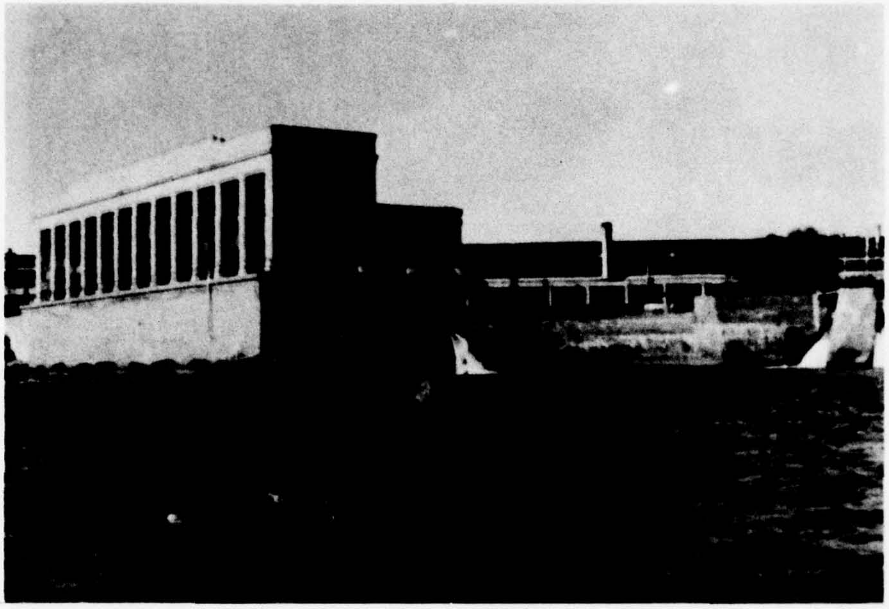


Figure 2.6 Overview of lock (bottom to top of page) looking upstream.



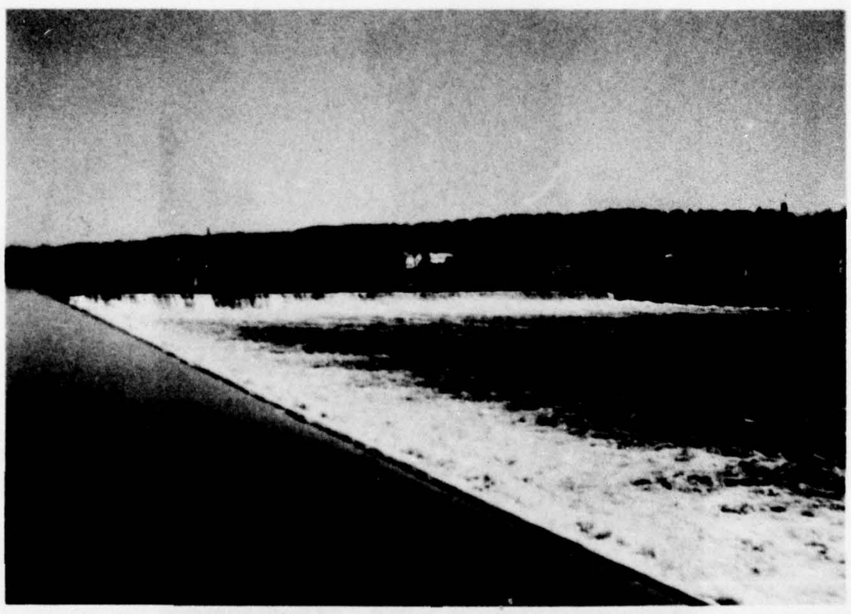


Figure 2.7 Overview of dam and powerhouse.

Figure 2.8 Landwall--upstream of upper miter gate viewing downstream.

Figure 2.9 Landwall--just upstream and to either side of operating station viewing downstream.

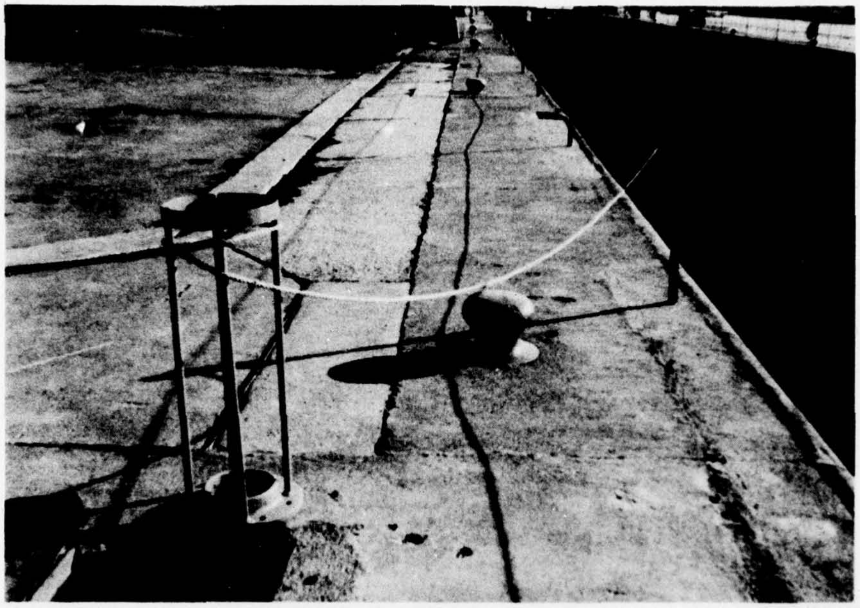


Figure 2.10 Landwall--view just upstream (bottom), then downstream (top) of upper miter gate.

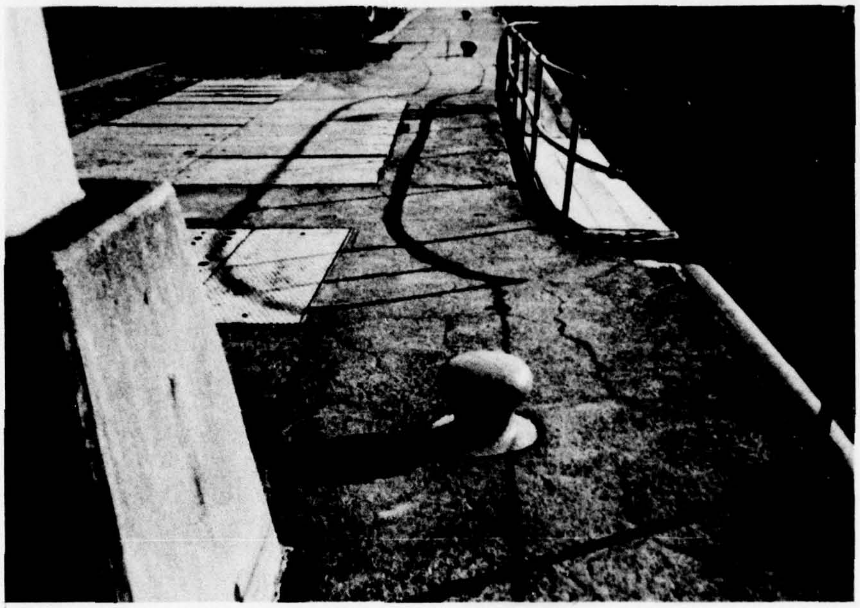


Figure 2.11 Landwall--downstream of upper miter gate but upstream of middle gate.

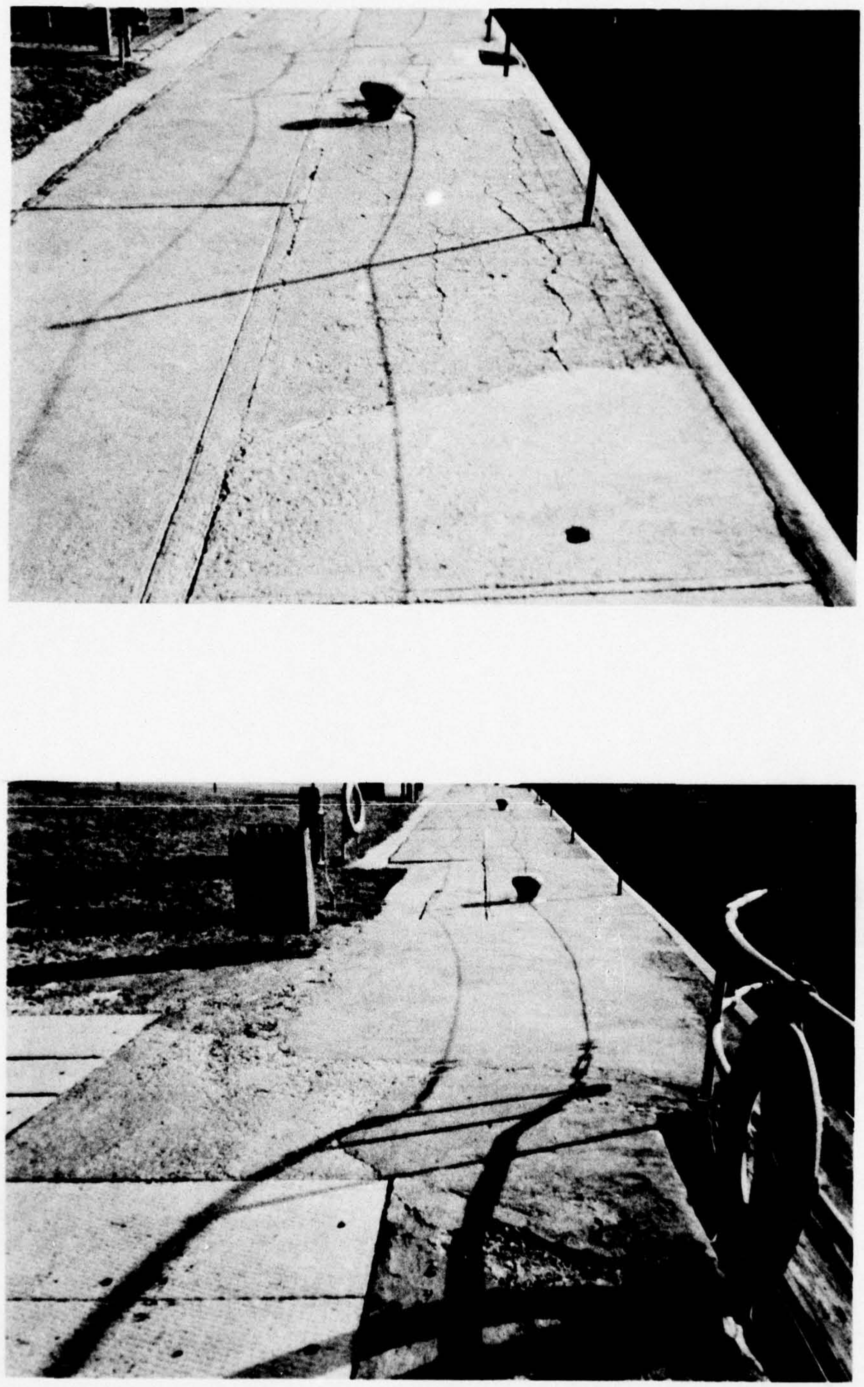
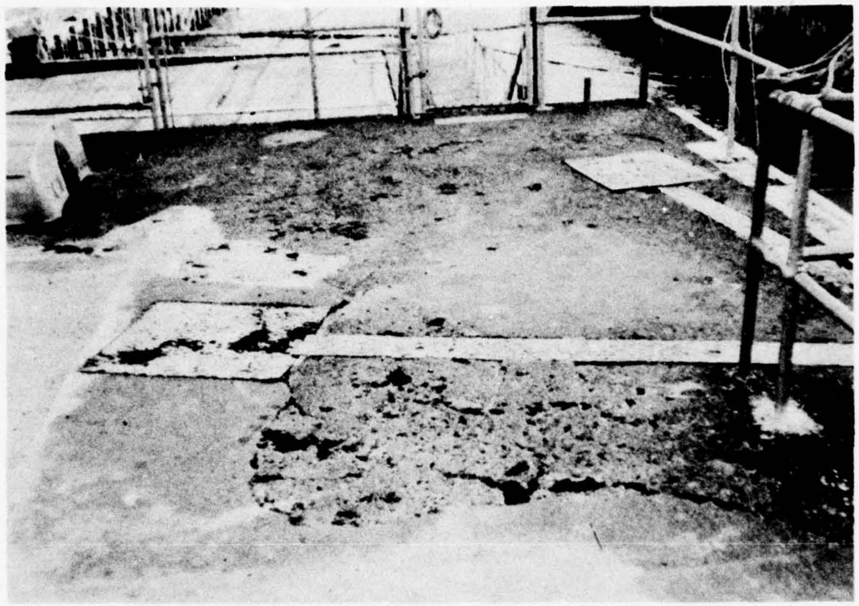


Figure 2.12 Landwall--at middle gate (bottom), below middle gate (top).

Figure 2.13 Landwall--upstream of lower miter gate.

Figure 2.14 Landwall--upstream and to riverside of operating station at lower miter gate.



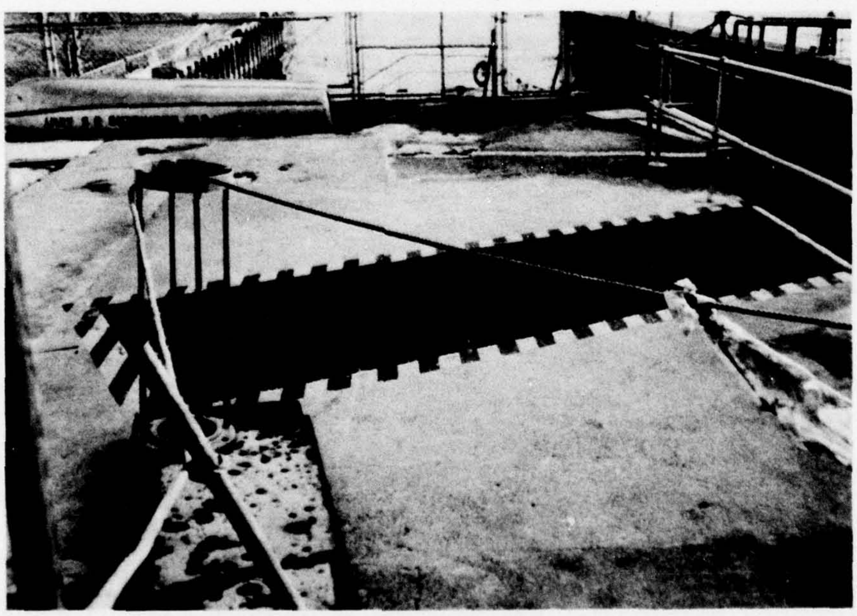
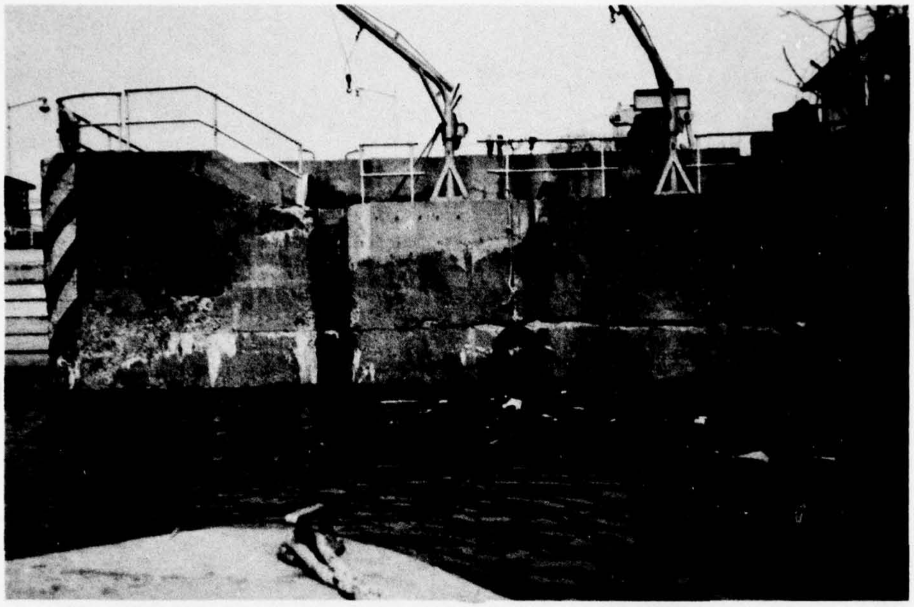


Figure 2.15 Landwall--at lower miter gate.



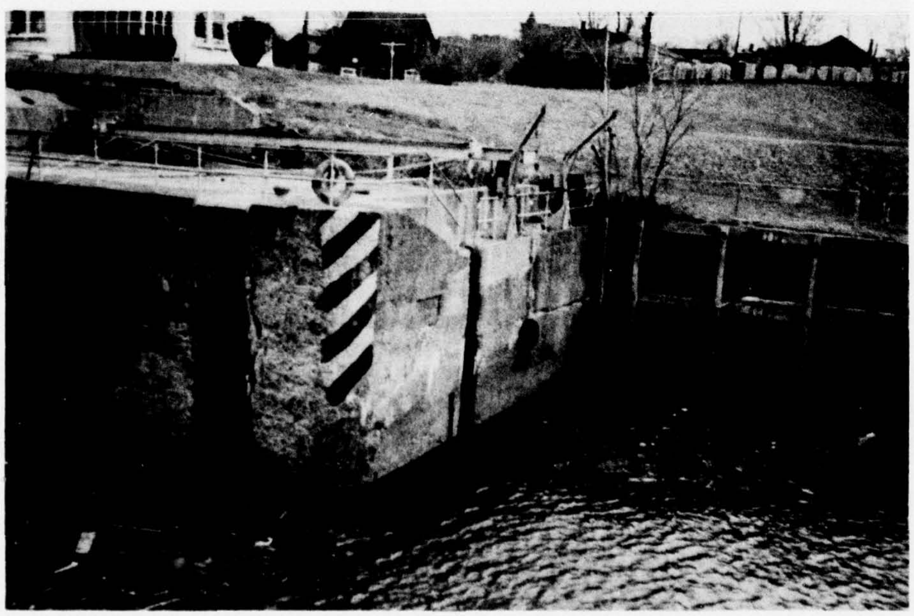


Figure 2.16 Landwall--downstream monolith.

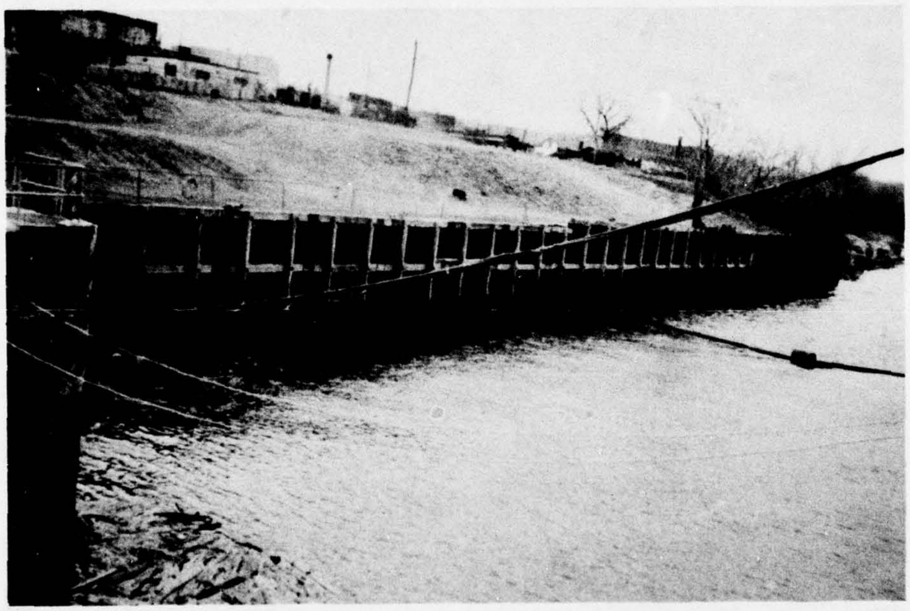
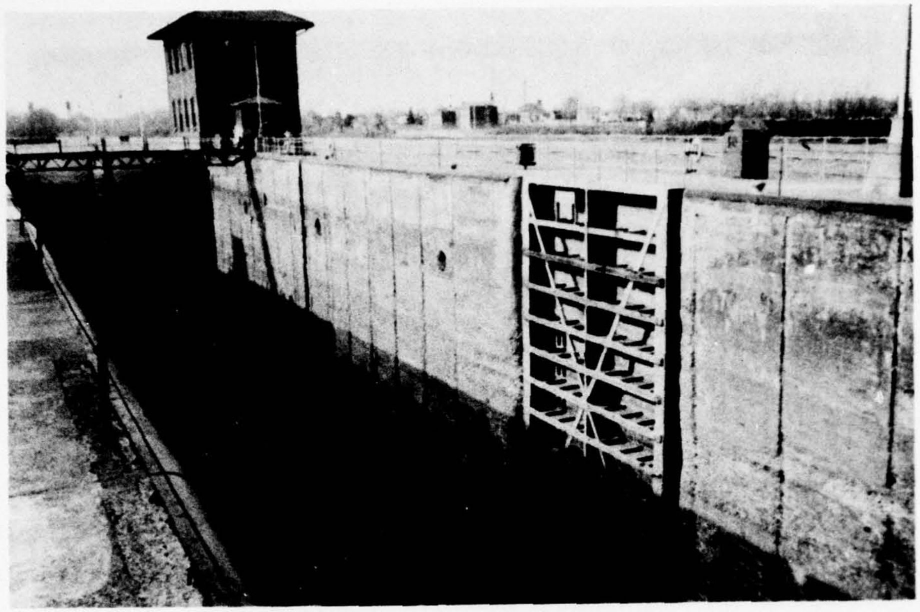


Figure 2.17 Landwall--downstream mooring wall.



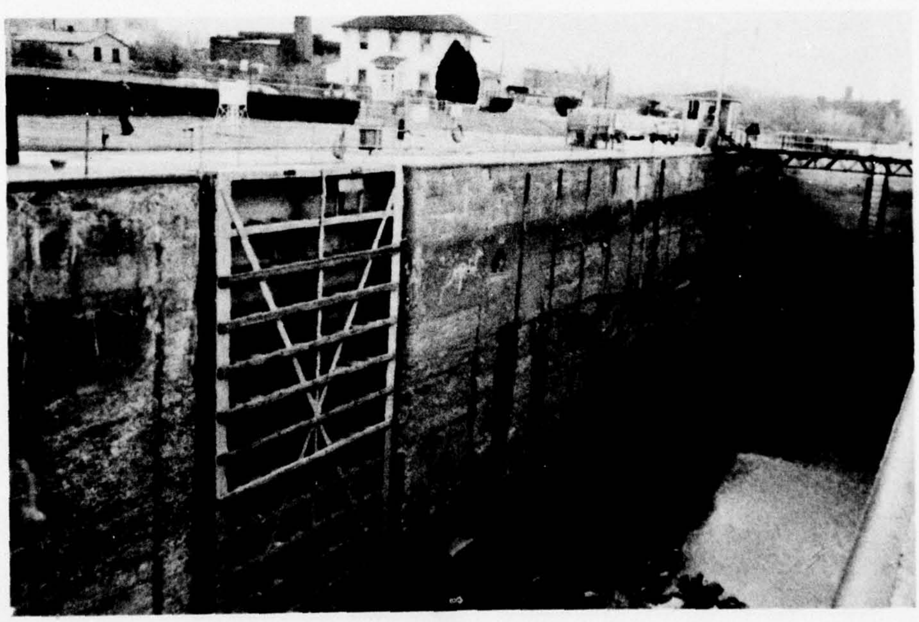


Figure 2.18 Typical view of lock chamber walls, bottom to top of page views land-wall then riverwall.

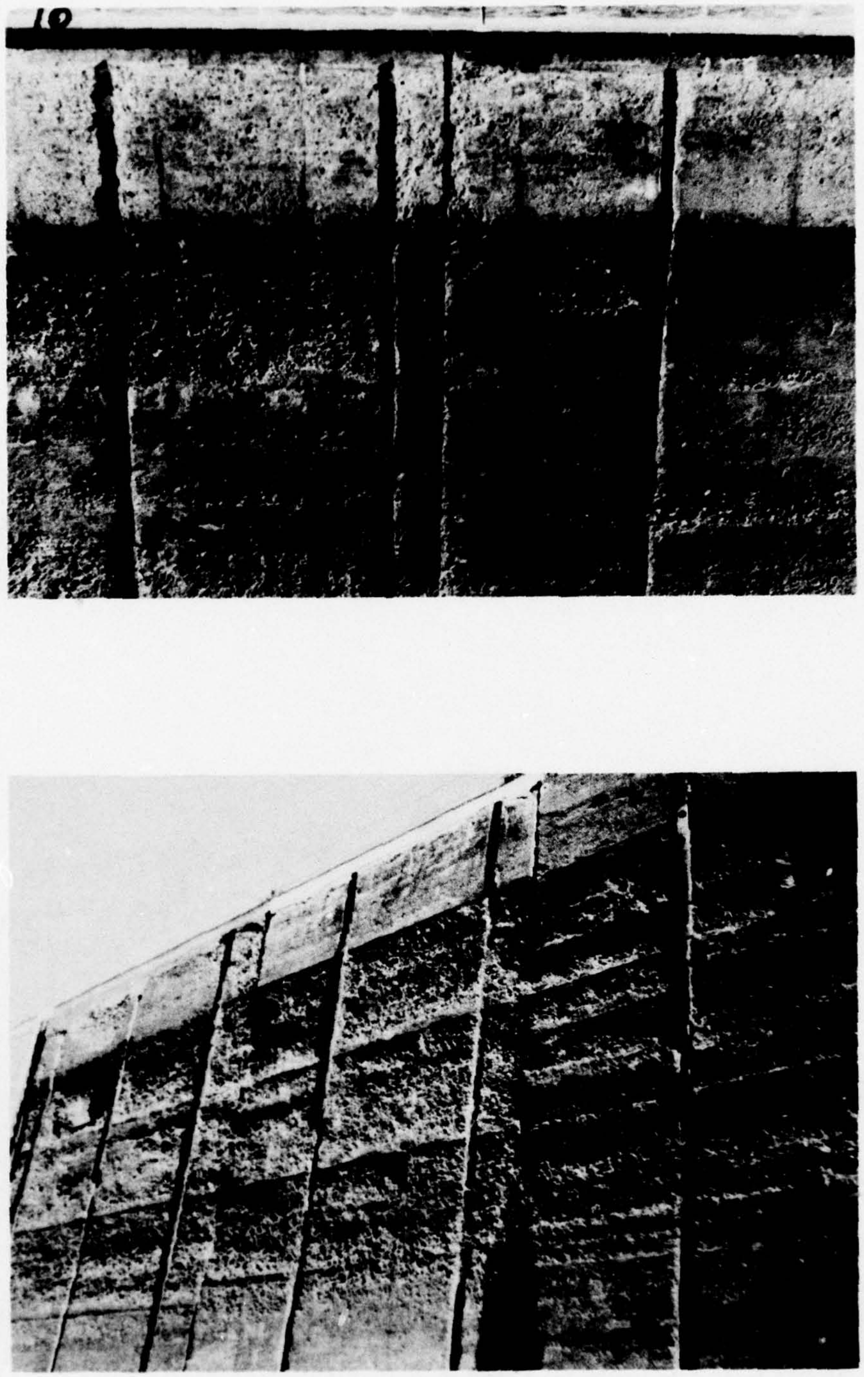


Figure 2.19 Typical detail views of lock chamber walls.

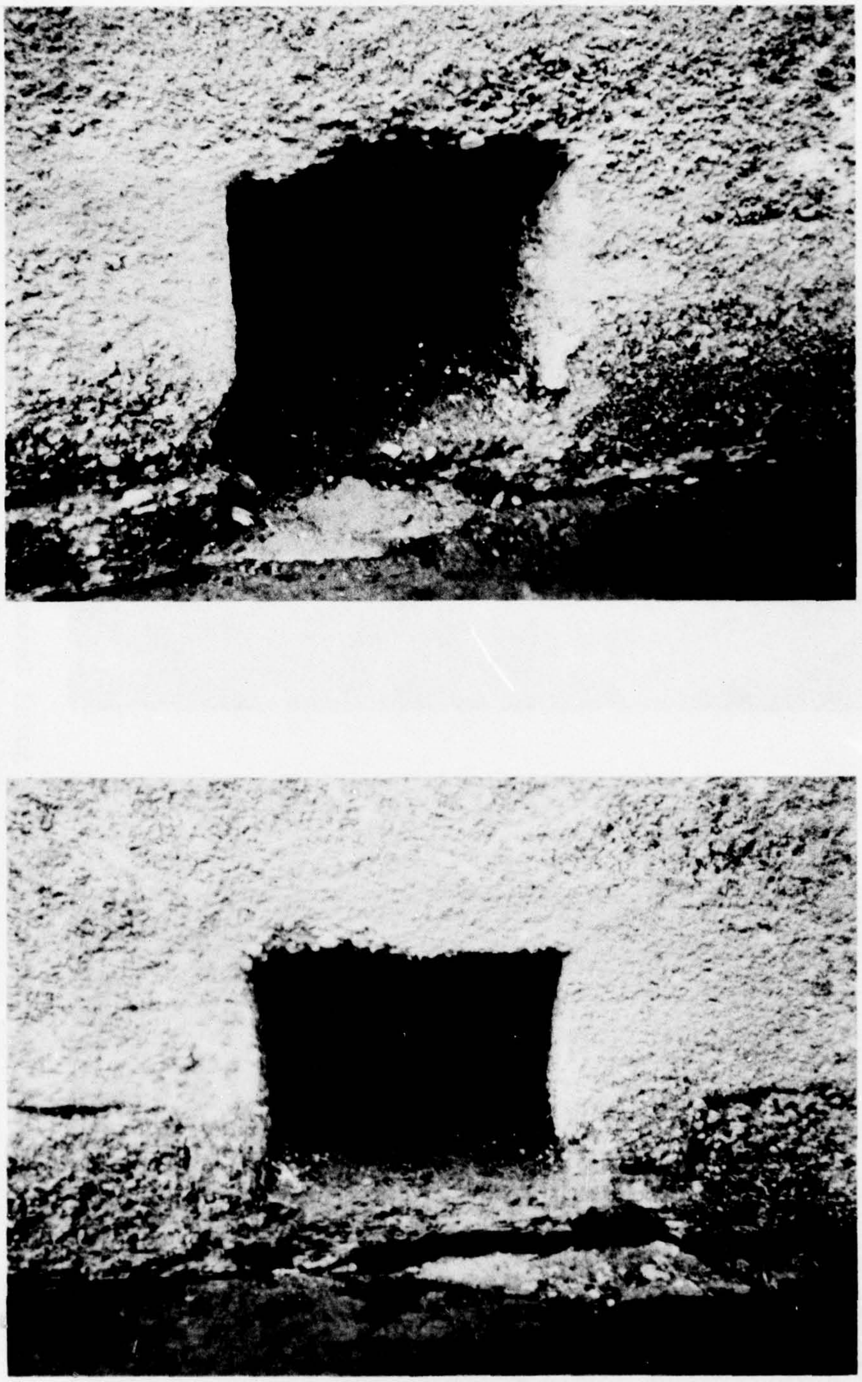


Figure 2.20 Typical view of filling and emptying ports.

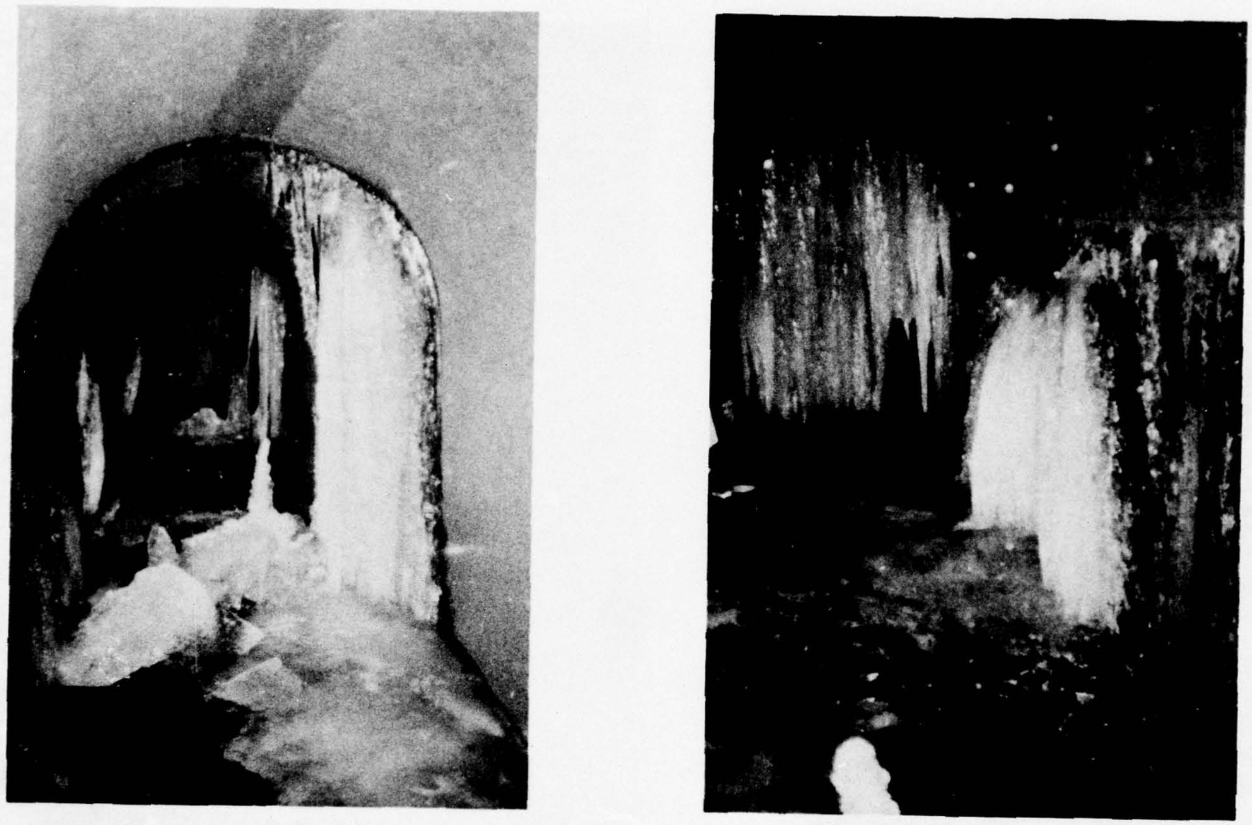


Figure 2.21 Typical view of construction joint leakage in riverwall filling and emptying culverts as portrayed by ice sheets.

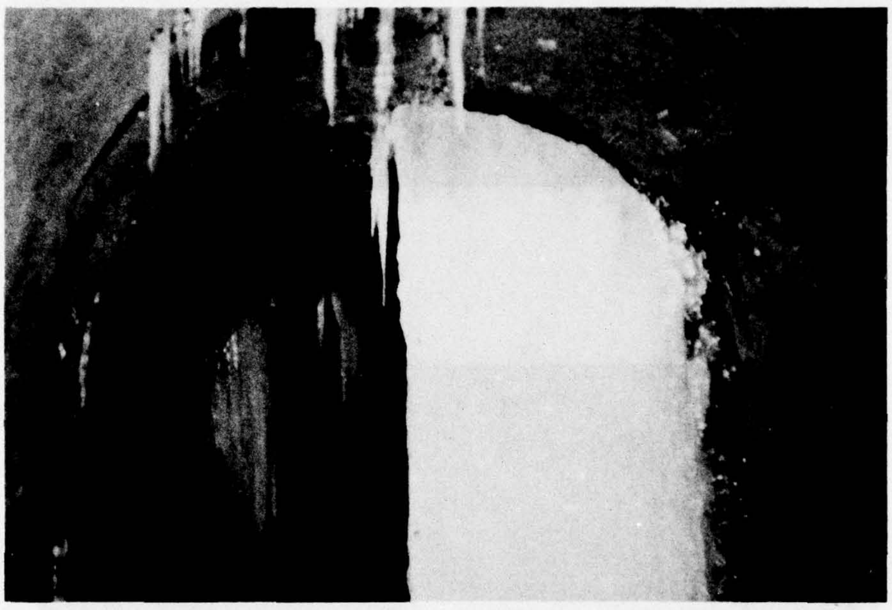


Figure 2.22 Typical view of construction joint leakage in landwall filling and emptying culverts as portrayed by ice sheets.

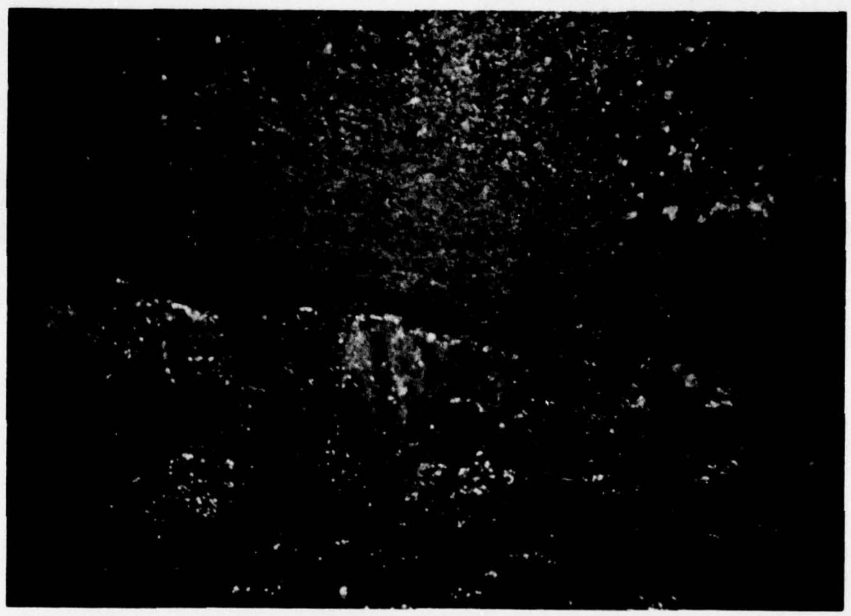


Figure 2.23 Mud and water flow through the wall of monolith 5 into the filling and emptying culvert of the landwall.

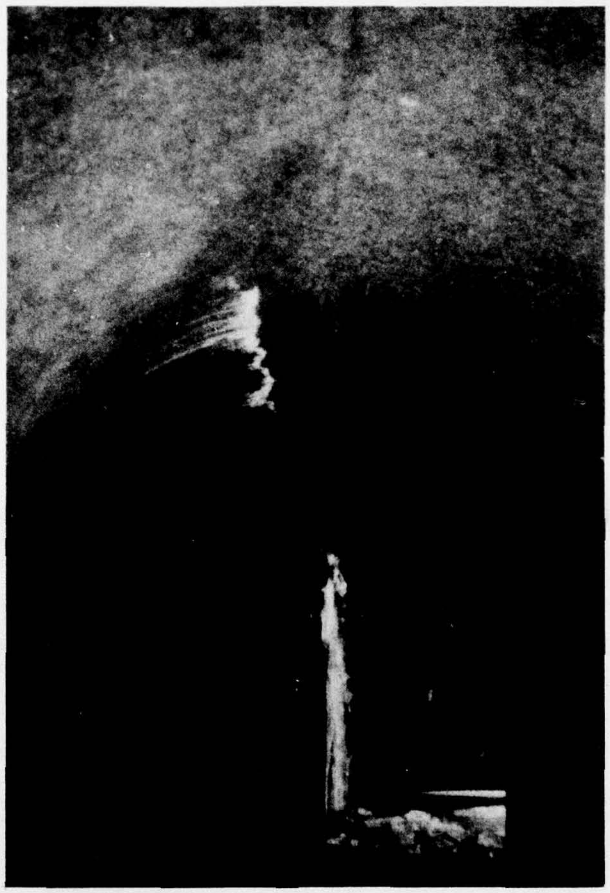
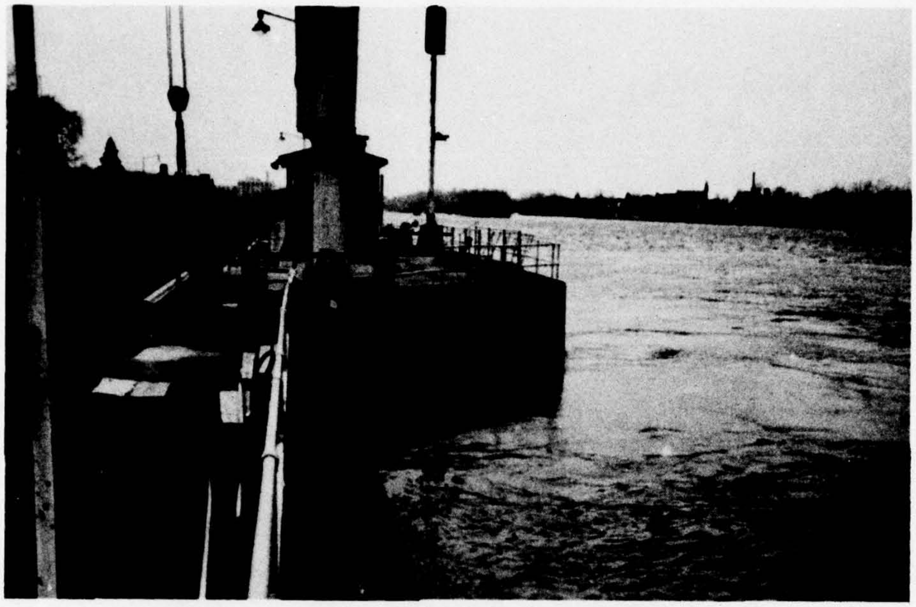


Figure 2.24 Cracking in top of downstream landwall filling and emptying culvert near exit below lower miter gate.



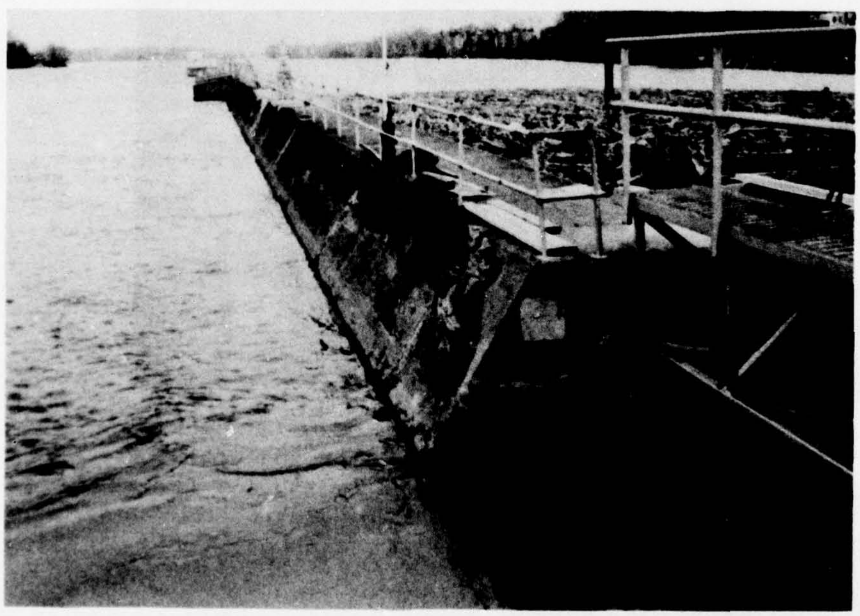
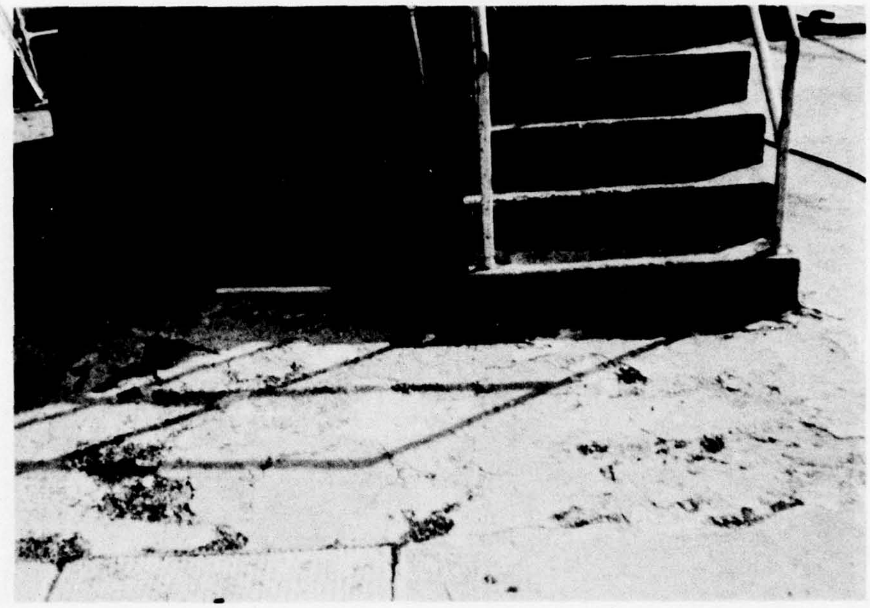


Figure 2.25 Original and newer guide wall looking upstream (bottom) to downstream view of beginning of riverwall (top).



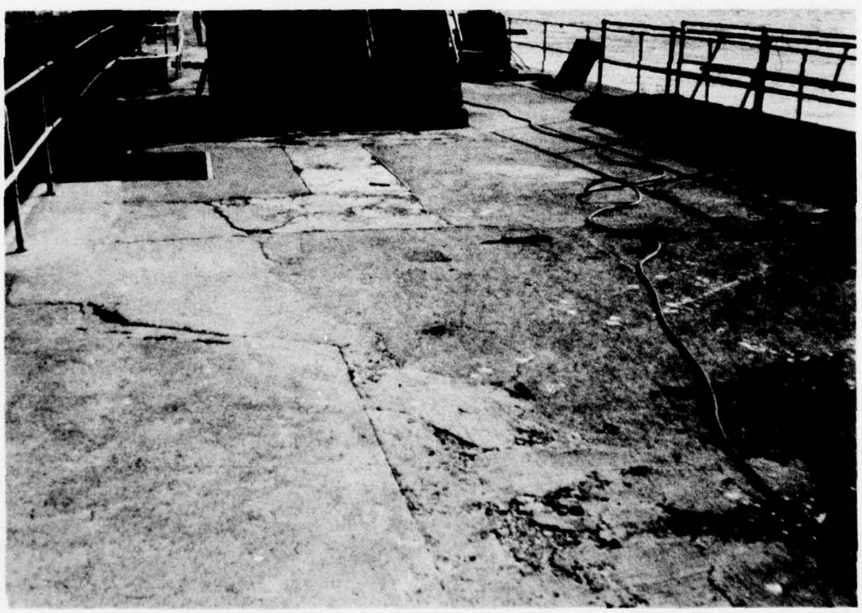


Figure 2.26 Riverwall--surface concrete deterioration at the first operating station upstream of upper miter gate.

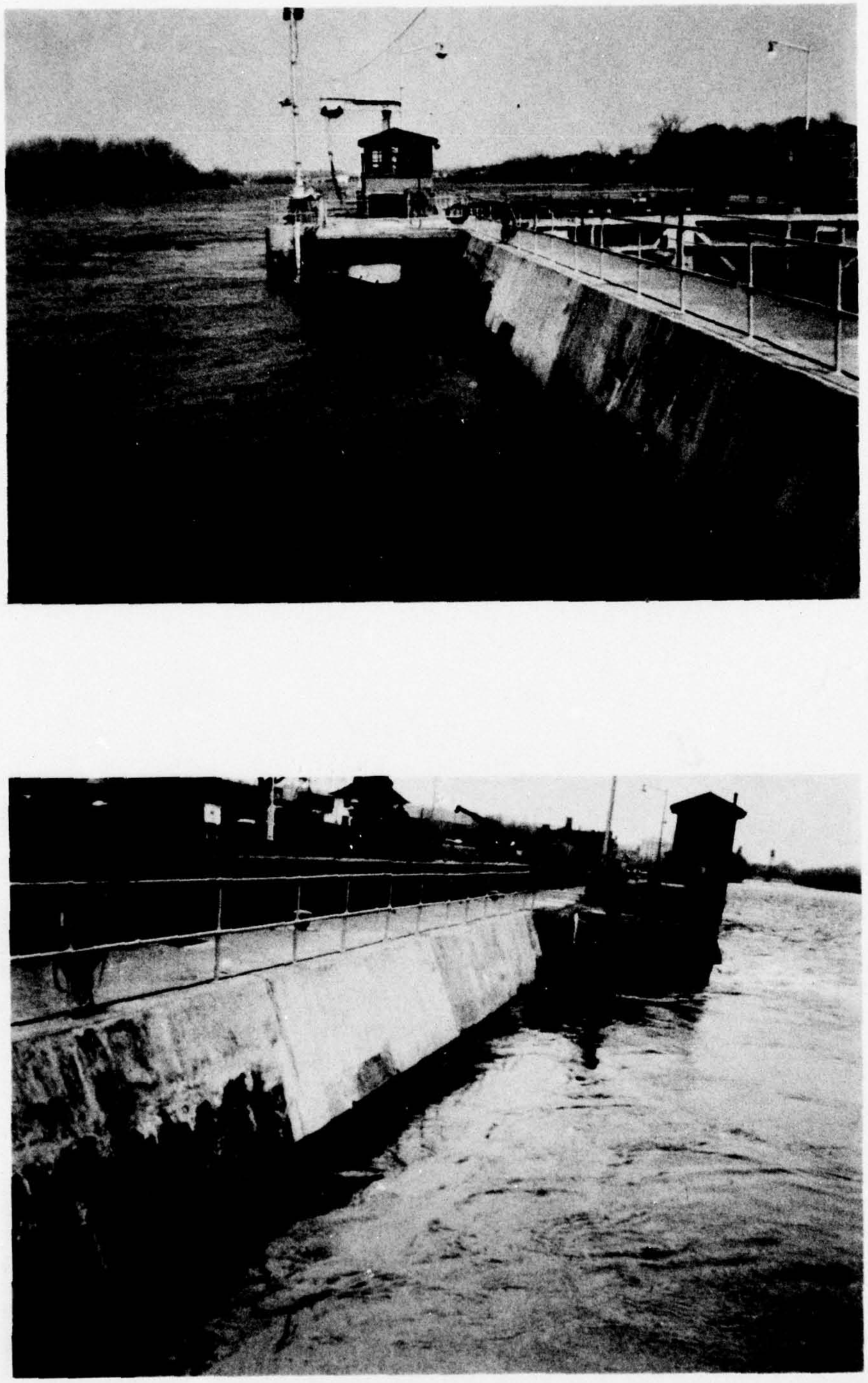
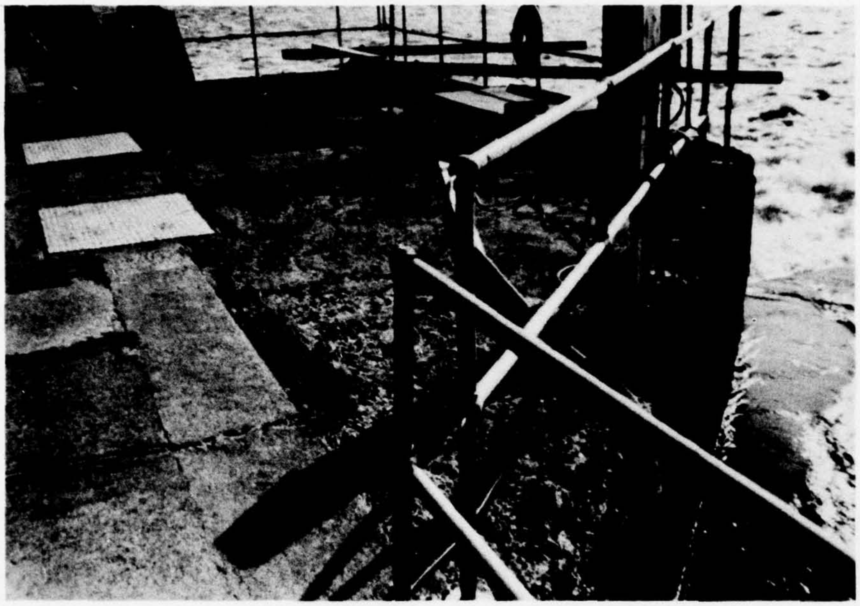


Figure 2.27 Riverwall--upstream of where the dam joins the riverwall.



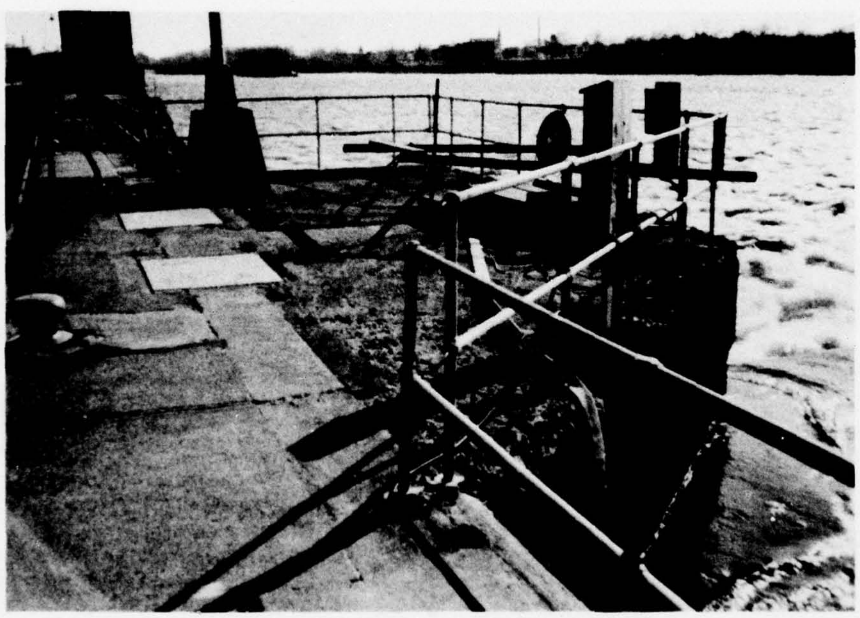
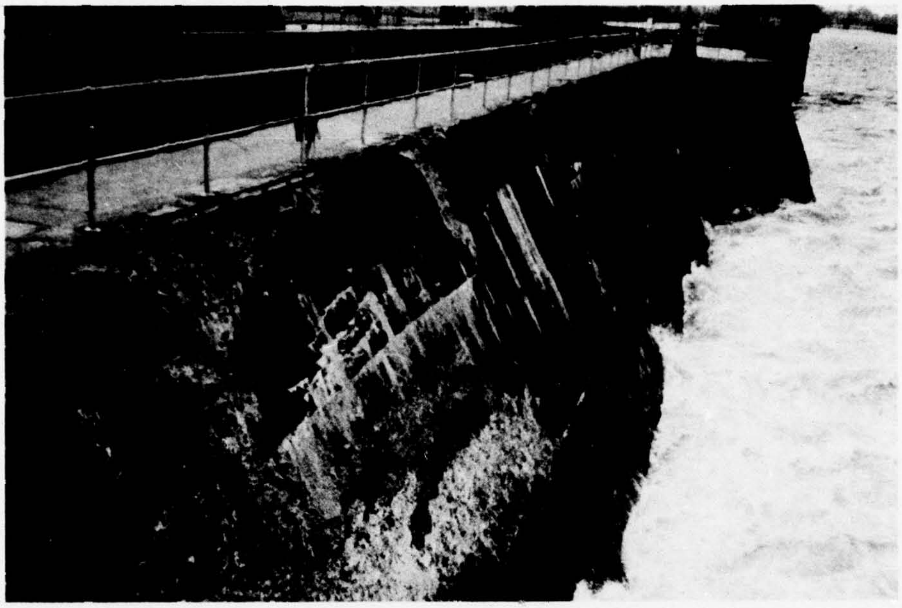


Figure 2.28 Riverwall--location where dams join riverwall.



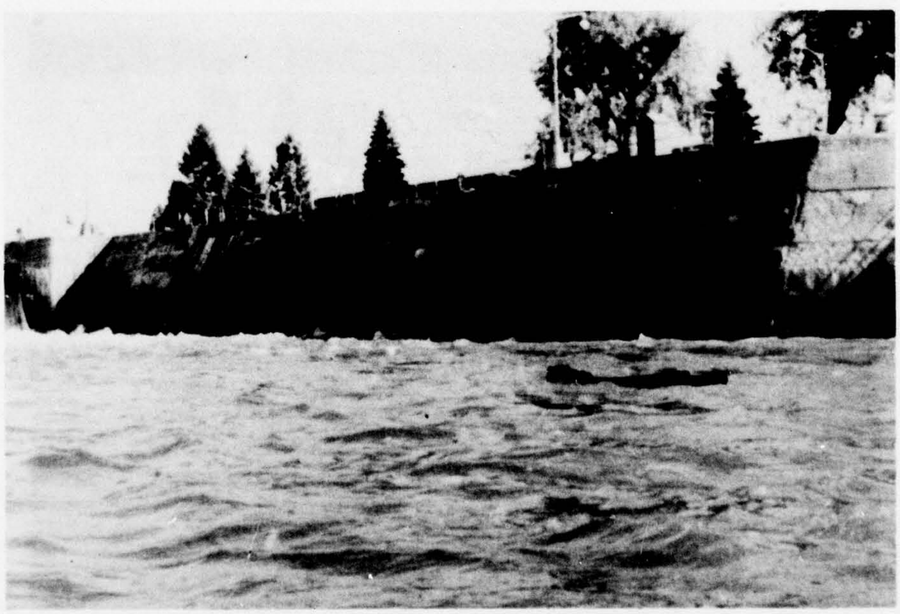


Figure 2.29 Riverwall--just downstream of intersection of dam to riverwall (bottom, looking upstream) and viewing the same wall downstream (top).

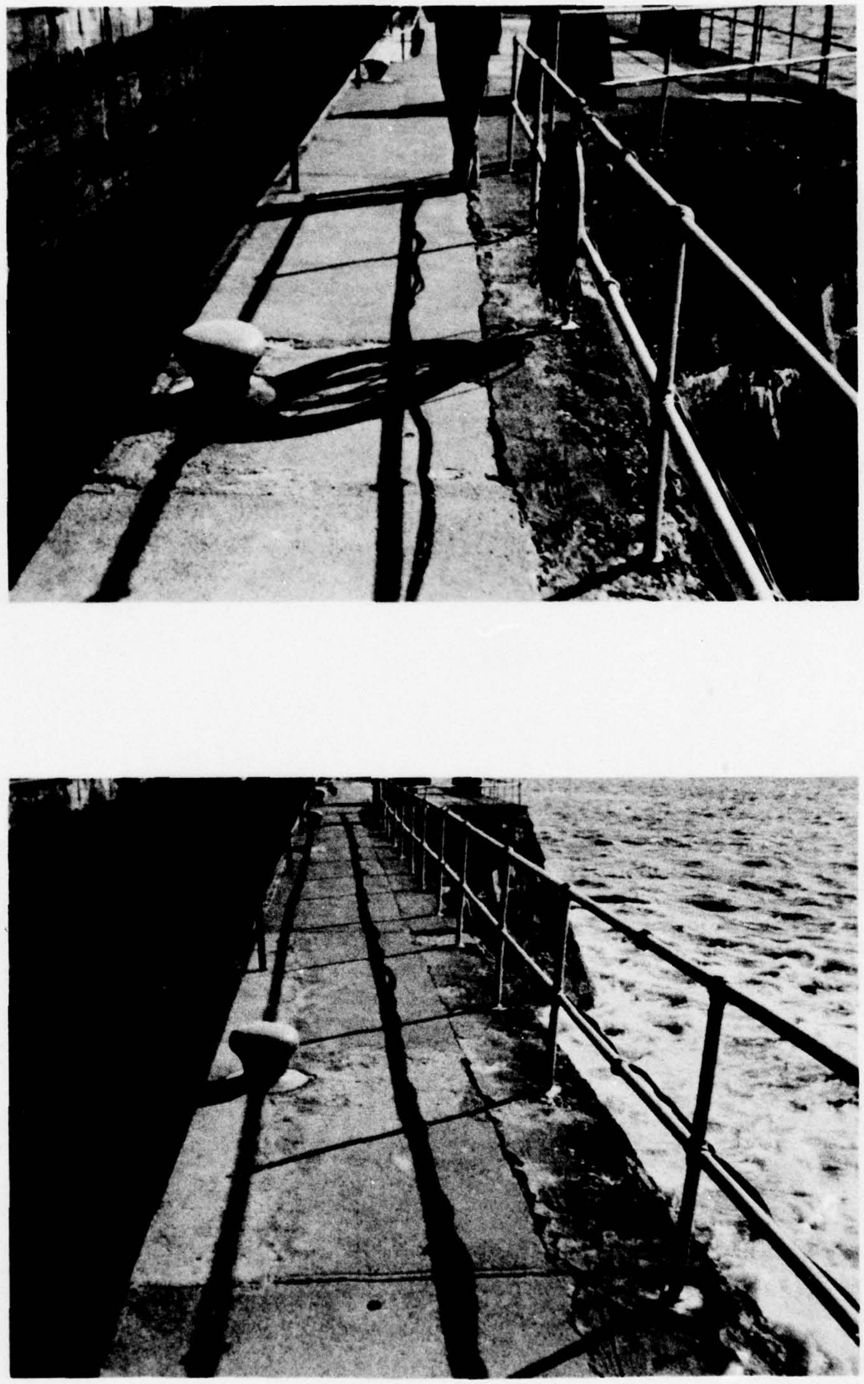


Figure 2.30 Riverwall--continuing upstream to downstream.

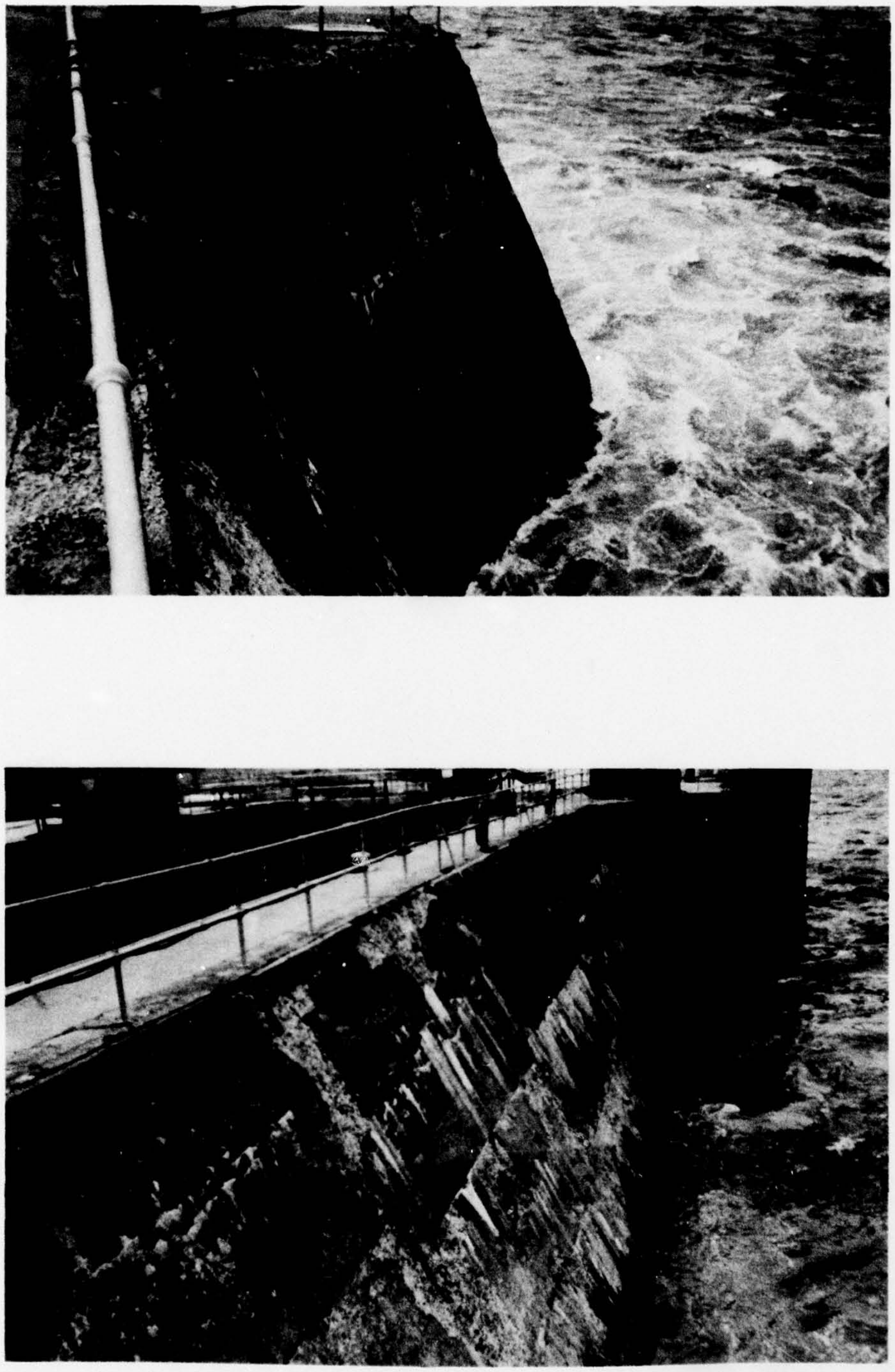


Figure 2.31 Riverwall--just upstream of operation building.

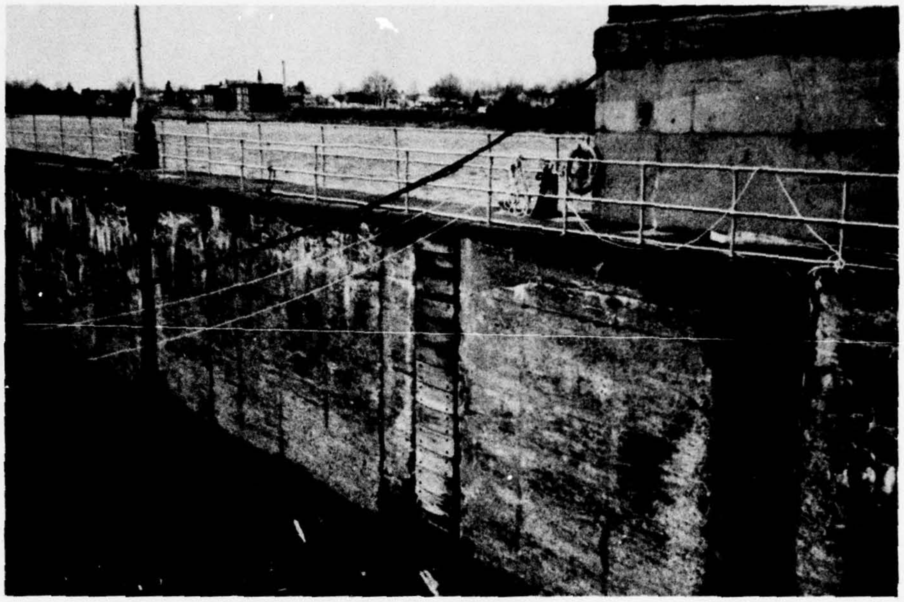


Figure 2.32 Riverwall--just above (bottom) and below (top) operation building.

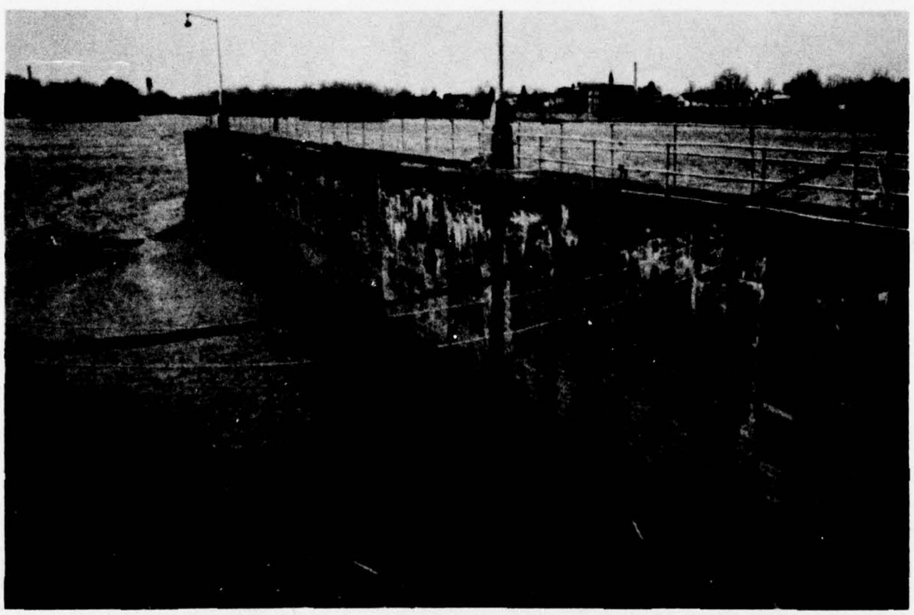


Figure 2.33 Downstream guard wall--landside (bottom) and downstream nose (top).

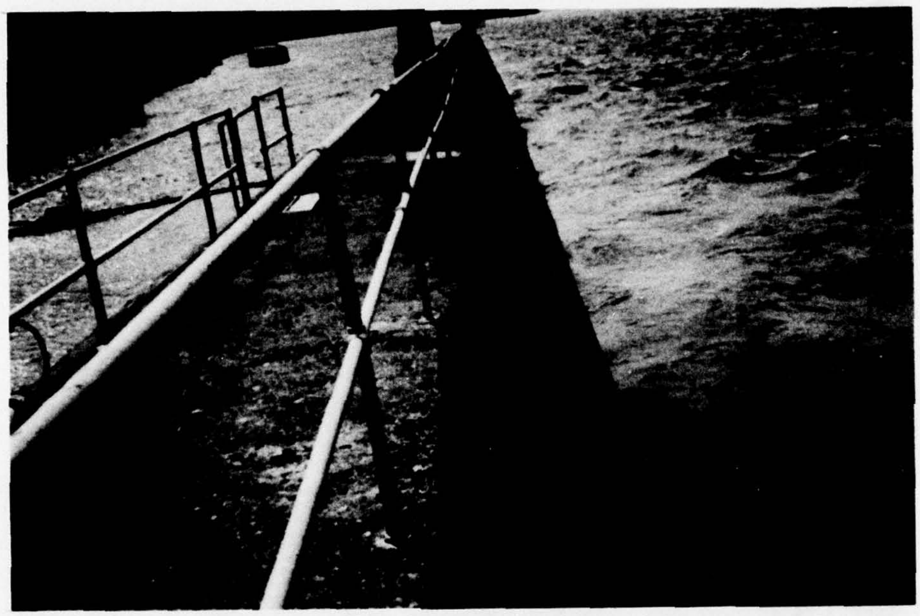


Figure 2.34 Top and riverside of downstream guide wall (downstream view).

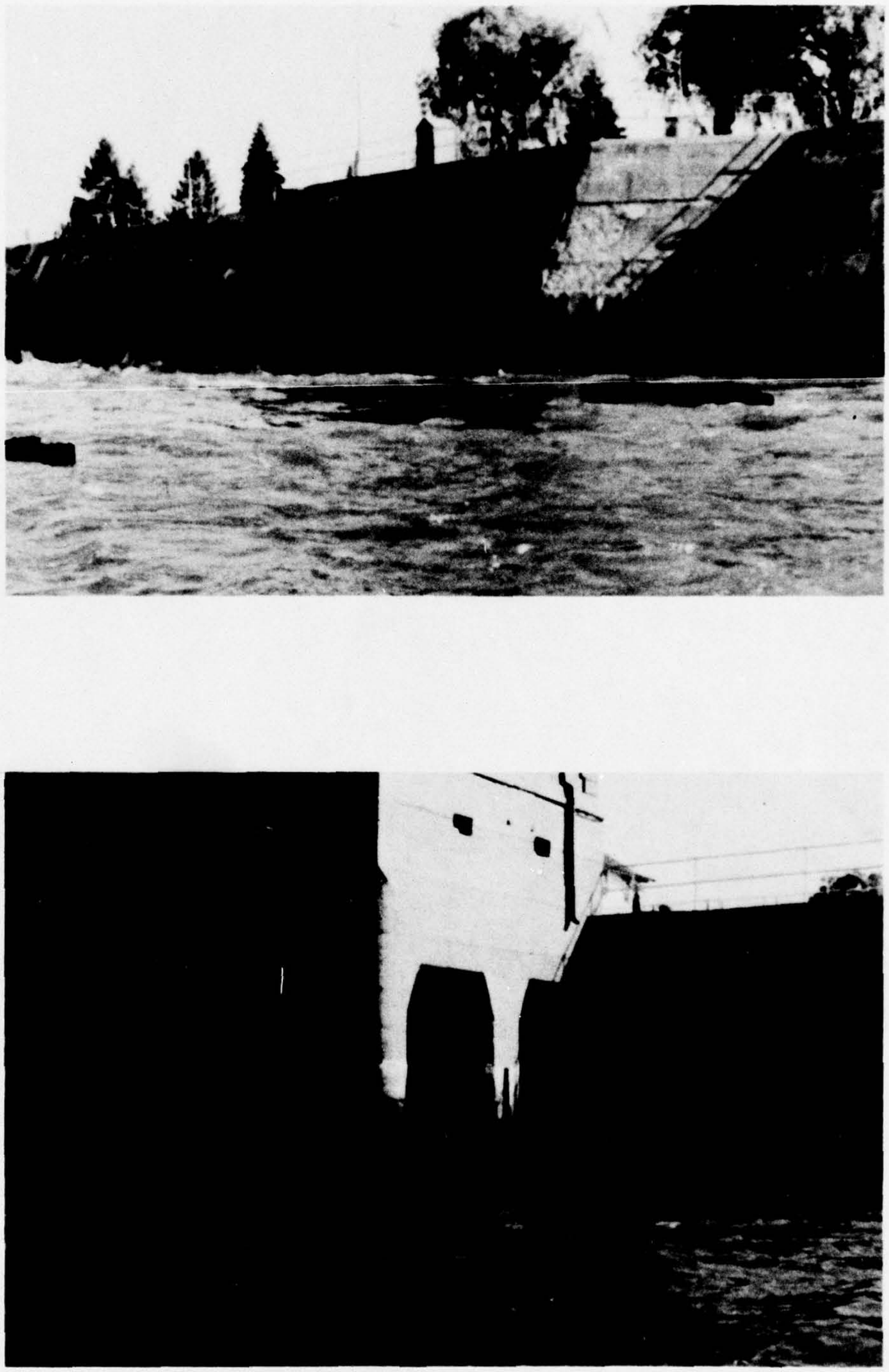


Figure 2.35 Reduction in section of operation building (bottom) and riverside riverwall (top). Water flow through construction joint of riverwall (top).

Figure 2.36 Water flowing from construction joint in riverwall from power tunnel.

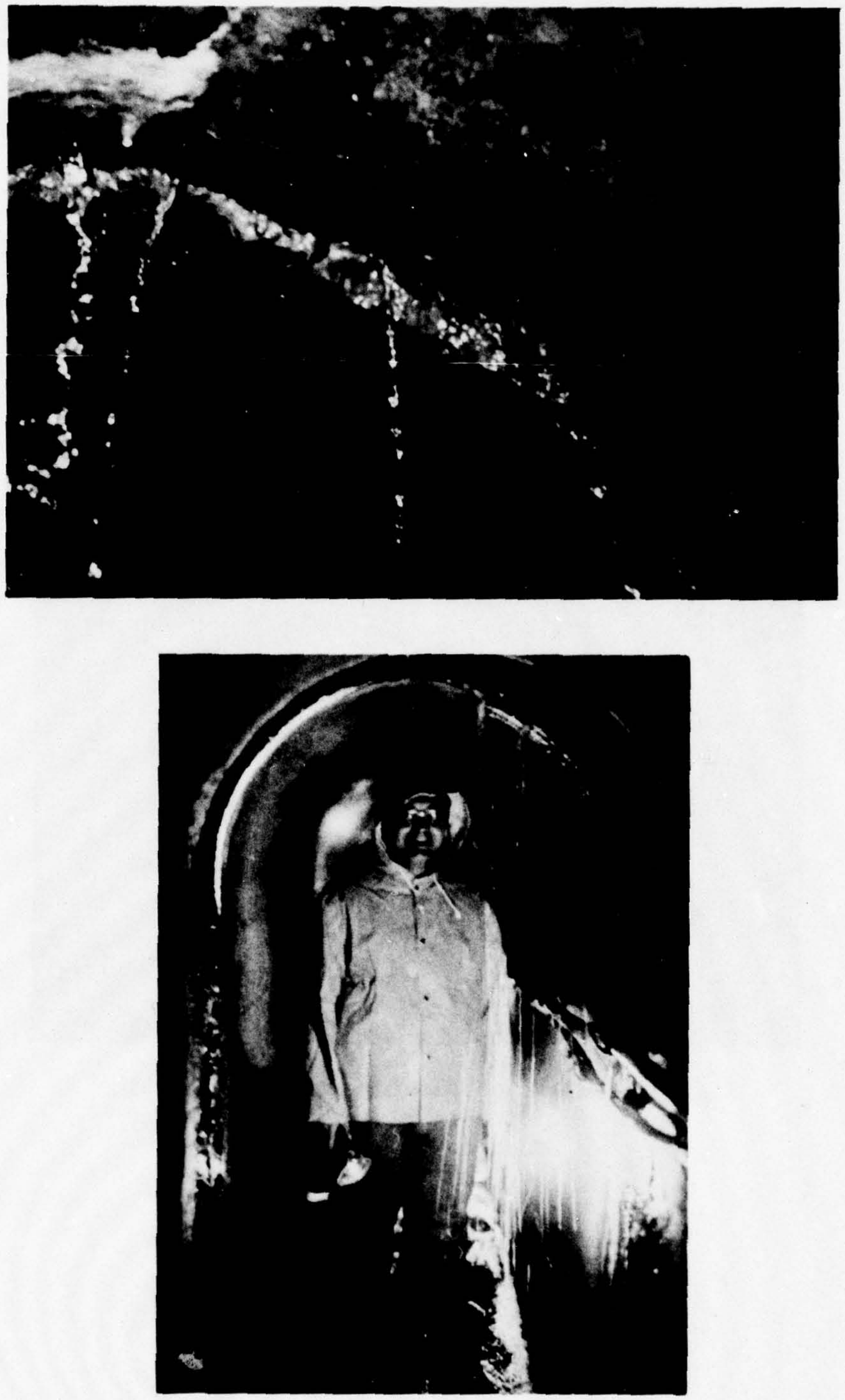


Figure 2.37 Leaking construction joints in dam tunnel.

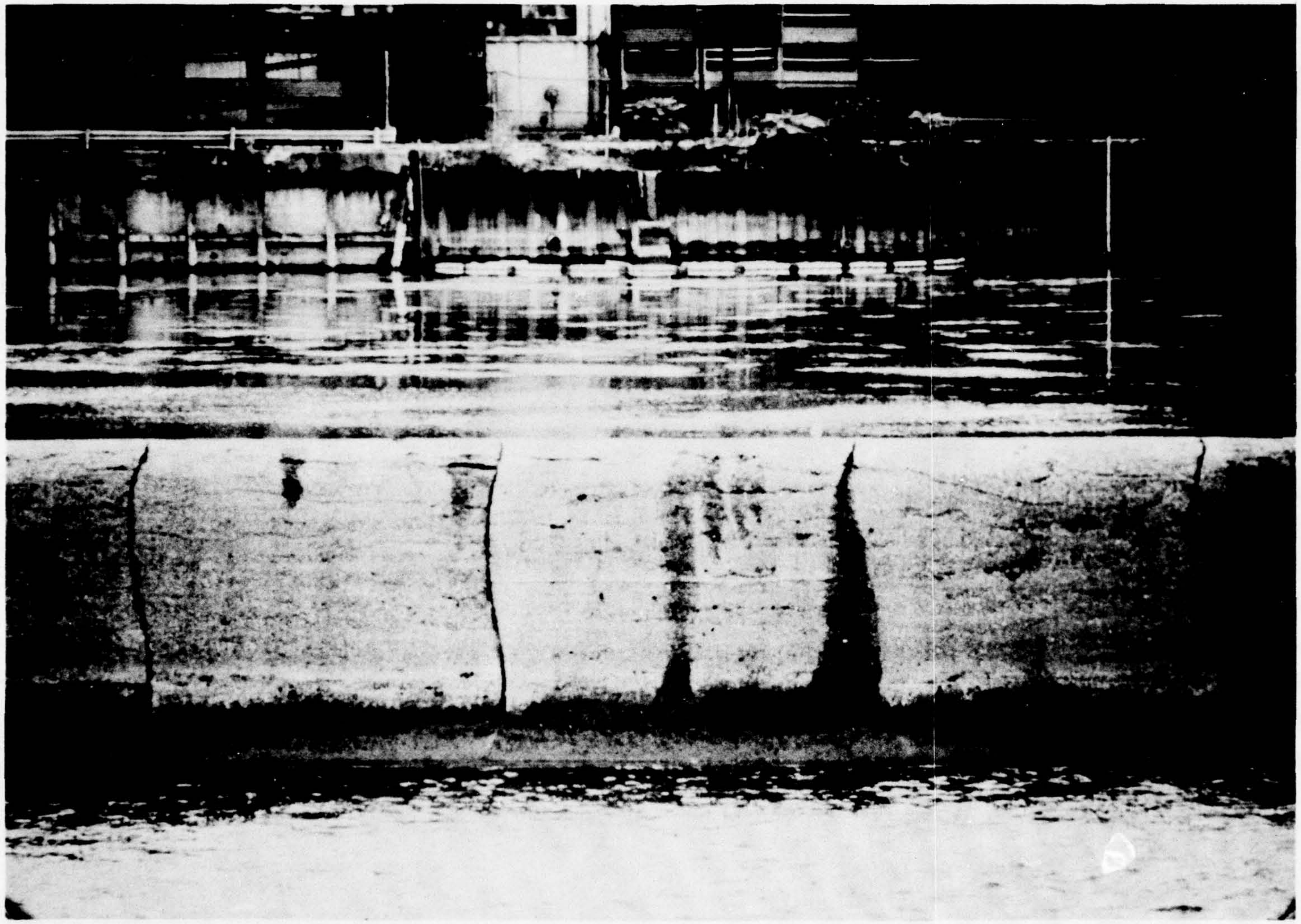


Figure 2.38 Deterioration of dam monoliths (D23, D24, and D25).

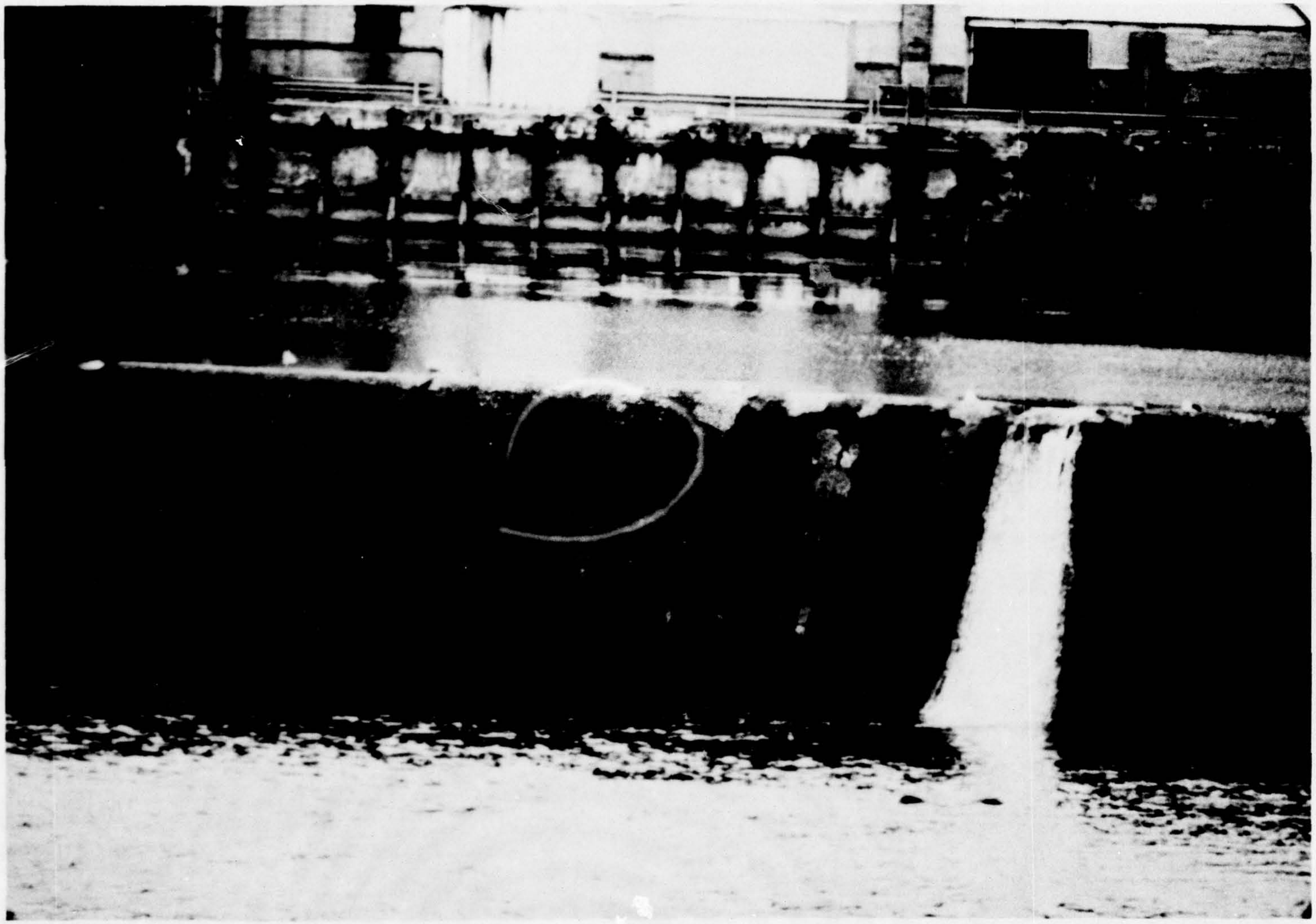


Figure 2.39 Deterioration of dam monoliths (D12, D13, D14, and D15).

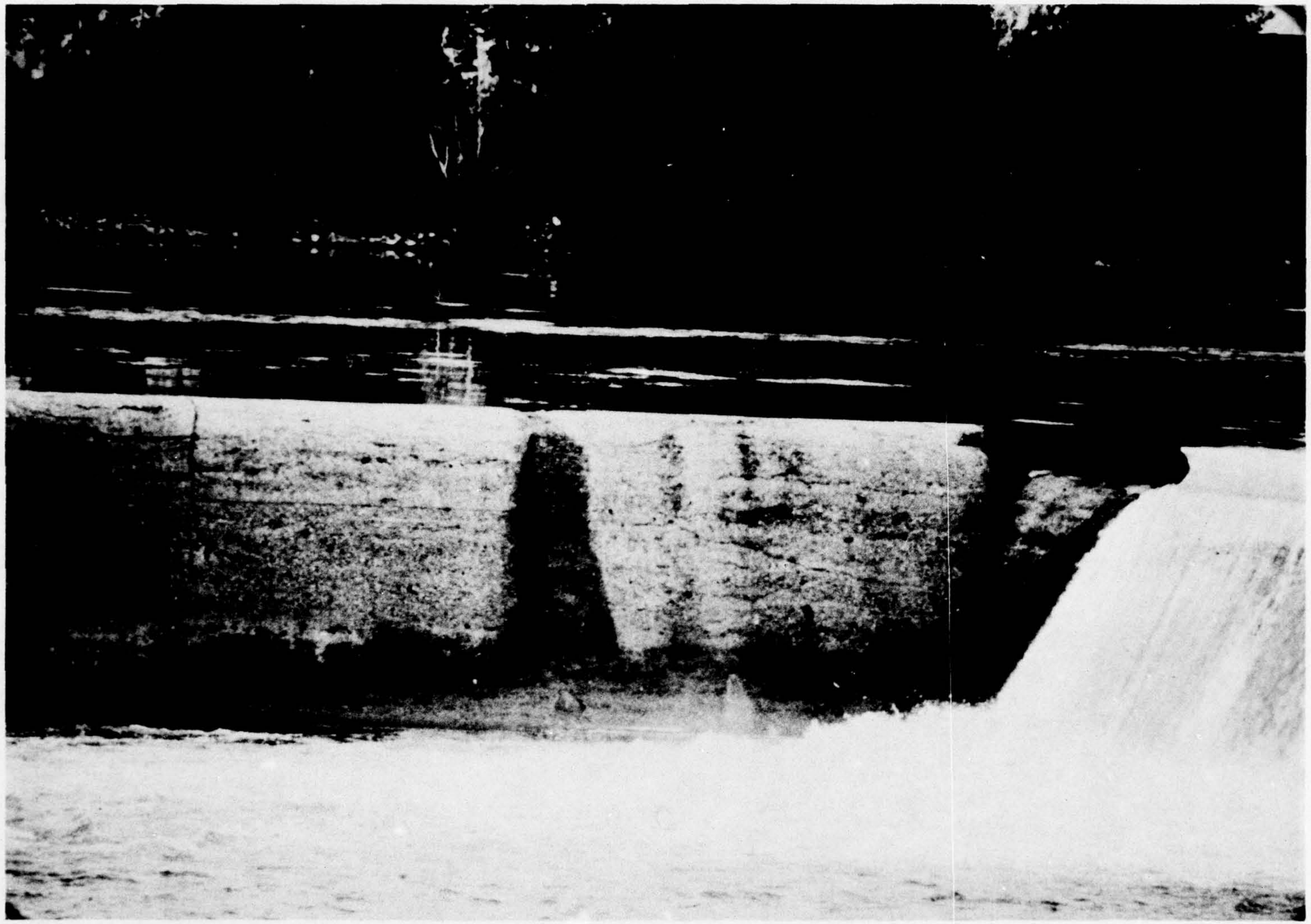


Figure 2.40 Deterioration of dam monoliths (D32, D33, and D34).

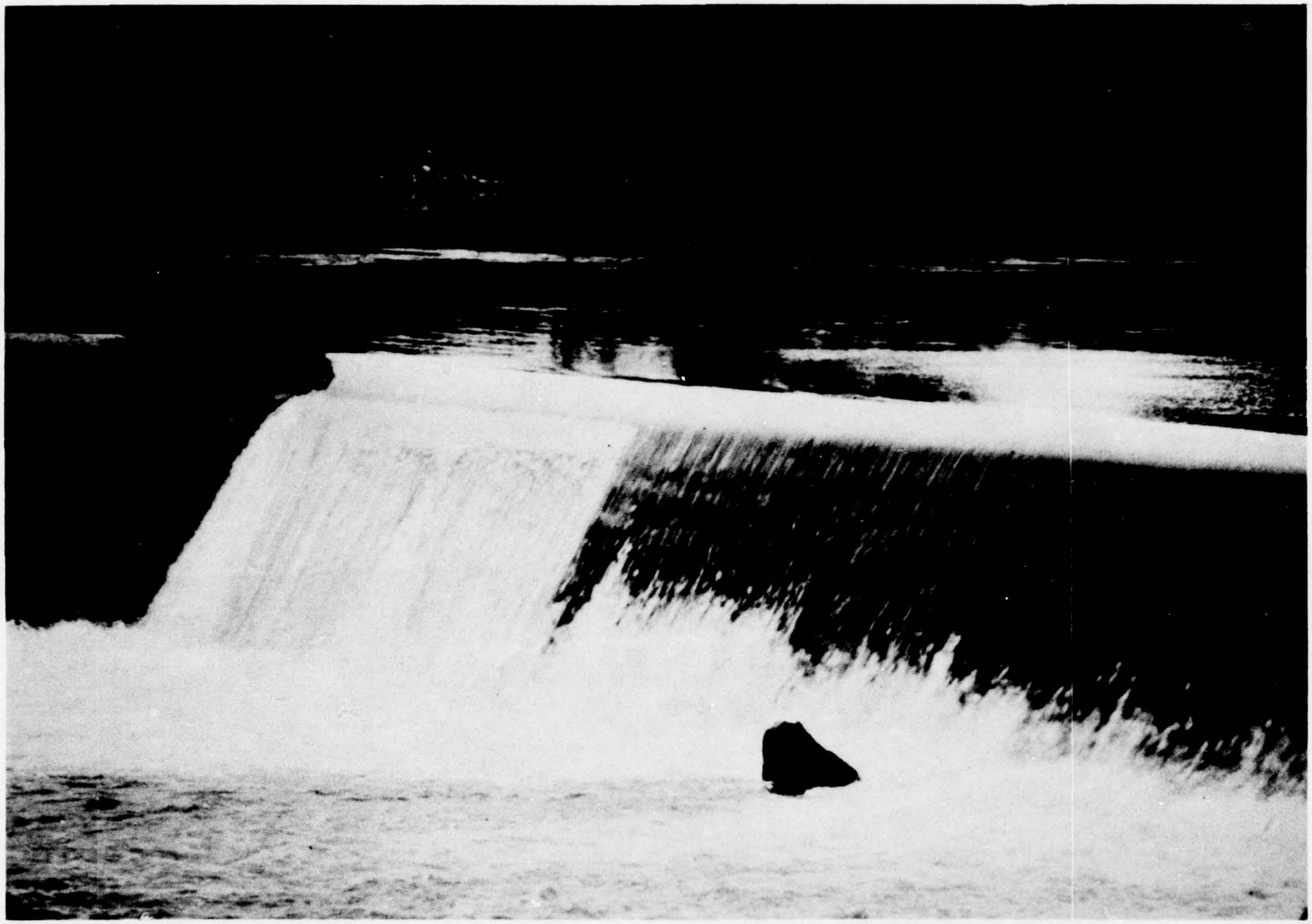


Figure 2.41 Deterioration of dam monoliths and rock protruding above water surface below dam.

Figure 2.42 Cracking and deteriorated surface concrete in the piers of the gated section near powerhouse.

Figure 2.43 Leaching in piers of gated section near powerhouse.

Figure 2.44 Cracking in the shaft which allows entrance to the dam tunnel.

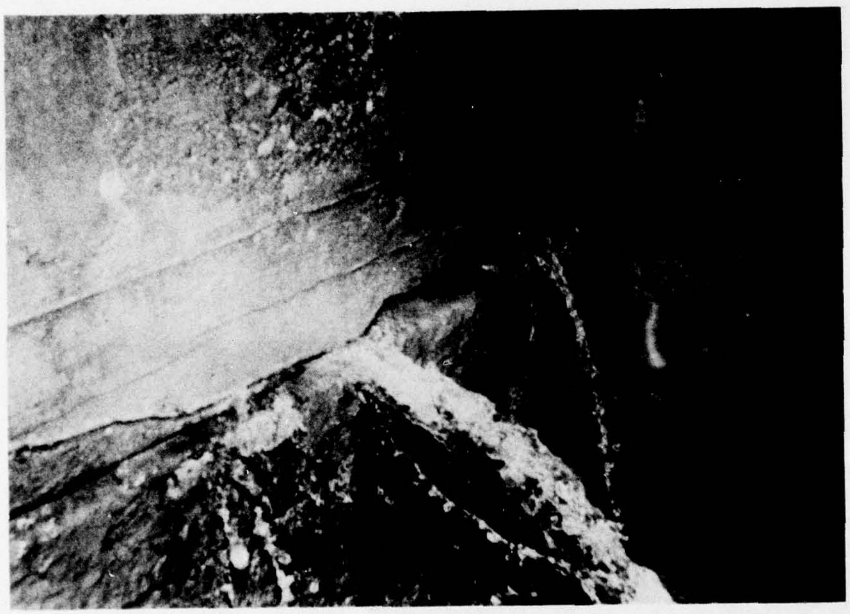


Figure 2.45 Leaking construction joint in the shaft which allows entrance into the dam tunnel.

PART III: CONCRETE INTEGRITY

38. Significant facts were determined from certain studies made during the Phase I investigation. The studies which revealed significant information about the concrete were:

a. Concrete cracking.

b. Surface concrete deterioration.

c. Ultrasonic velocity measurements.

d. Rebound number tests (CRD-C22)*

e. Water quality tests.

39. The crack survey revealed that structural cracking is not significant in the lock. The cracking in the dam is significant in two areas only as was discussed in Part II. The concrete cracking in Troy Lock and Dam is, therefore, such that repair and maintenance are practicable.

40. The surface concrete is deteriorated such that it must be repaired in the near future. Three immediate concerns about the deterioration of the lock are:

a. Extent of deterioration in areas of undercut at the level of main tidal fluctuation (base of main control house and river wall).

b. Depth of deteriorated surface concrete for removal and repair.

c. Construction joint deterioration.

41. The main concerns for integrity of the concrete in the dam are:

a. Deteriorated surface condition of dam and gated section.

b. Contact of the dam monoliths with the foundations.

c. Construction joint deterioration.

d. Cracking in the shaft of the entrance to the dam from powerhouse side of river.

e. Vibration of dam monoliths due to water forces.

f. Cracking in the piers of the gated section next to the powerhouse.

The considerations about the lock and considerations a, b, c, d, and f concerning the dam can adequately be evaluated by taking and testing cores from the lock, dam, and gated section.

---

* See footnote on page 66.

42. An ultrasonic pulse velocity investigation was made to determine the general quality and variations in quality of the concrete in the lock walls. The investigations showed the interior concrete to be of good quality. These results should be correlated with strength tests of concrete cores to quantitatively verify the actual concrete strengths. The ultrasonic tests are discussed below.

43. The test equipment and procedure used in the ultrasonic investigation are described in test method CRD-C 51-68.*

44. When surveying a structure of this type, it is desirable to send sound waves through the entire cross-section of walls in as many areas as are accessible. At one-lock structures, such as the Troy Lock, only the river wall and the lock sidewalls of the filling and emptying culverts can be assessed.

45. Since Troy Lock was dewatered, the only practicable alternatives were:

- a. Make measurements through the top of the wall at an elevation that could be reached by holding the transducers down either side of the wall.
- b. Make measurements through sections of the walls in the vicinity of the filling and emptying ports.

46. It was felt that these two areas would represent the two extremes in the condition of the concrete, i.e., poorest near the top of the wall and best in the filling and emptying culvert walls. Experience in ultrasonic testing indicates that the relation between velocity and quality of concrete of normal density is approximately as shown in the following tabulation. It should be noted, however, that these values are only typical and cannot be expected to apply in all instances.

Pulse Velocity, fps	Condition
Above 15,000	Excellent
12,000-15,000	Generally good
10,000-12,000	Questionable
7,000-10,000	Generally poor
Below 7,000	Very poor

* Handbook for Concrete and Cement, WES, Aug 1949, with quarterly supplements.

47. Velocity measurements were made through the river wall at 5-ft intervals, where practicable, between stations No.* 3+48 and 8+02, inclusively. The measurements were made at an elevation approximately 1.5 ft below the top of the wall. Table 3.1 gives the monolith number, station number, path length, velocity, and signal strength of all measurements made in this area of the structure. A study of the tabulated velocities and signal strengths indicates that the quality of the concrete as originally placed may vary slightly between monoliths. The maximum deviation in the velocities that can be attributed to operator variation and inadvertent misplacement of transducers is 5 percent.

48. It should be noted here that discontinuities in the concrete through which the ultrasonic wave passes can cause attenuation and even complete loss of transmission of the signal, depending on the type, size, and condition of such discontinuities. A decrease in signal strength, with or without an appreciable decrease in velocity, is an indication of some form of discontinuity. The discontinuity may be sharply defined, such as a crack, or it may be generally distributed as breakdown in matrix or aggregate due to frost action or some type of reaction. There is also the possibility that voids exist within a structure because of poor placement procedures or inadequate consolidation. Many of the lower velocities were probably caused by a combination of shallow cracking and surface deterioration. Extensive scaling and spalling had taken place on the river face and hollow areas were located with hammers. Although efforts were made to avoid these hollow areas when making measurements, there is a good probability that some velocities reflect the effects of this condition. The range of velocities indicates varying degrees of distress of some nature in the top of the river wall. The exact causes of this distress cannot be determined using only the information obtained from the velocity survey. A selective coring program would allow correlation between velocities and concrete strength and condition.

---

* Station numbers were established by Concrete Laboratory personnel, using the upstream nose of the guard wall as Station No. 0+00.

49. Velocity measurements were made through sections of the land wall and river wall at elevation -10.0 msl (Tables 3.2 and 3.3, respectively). One measurement was made through the section of wall just above each of the 12 upstream ports in the land wall and river wall. The concrete in these areas seemed to be in generally good condition. The velocities obtained indicate generally good quality concrete. There were some fluctuations, but these are believed to be caused by the powdery condition of the surface concrete on the face of the chamber wall. About 1/4 in. of this powdery matrix was removed from around the aggregate with a wire brush before measurements were made, but there is a possibility that some remained and affected the signal strengths and velocities of a few readings. Except for this slight surface deterioration on the face of the chamber walls, the concrete seems to be in good condition.

50. The rebound number results ranged from 28 to 36. This indicates good compressive strengths between 3000 and 4000 psi. These results are consistent with the ultrasonic tests, but they should also be verified by testing concrete cores.

51. The water in the Hudson River was tested and does not contain deteriorating agents which would affect the concrete.

52. The evaluations in the Phase I study indicate that the integrity of the concrete below the deteriorated surface of the lock is of good quality.

53. The concrete core testing, petrographic analysis, and structural analysis to be conducted in Phase II of this project will be adequate for conclusions about what to do to obtain 30 to 50 years of future lock and dam usage. The necessary evaluation for the Phase II work will be discussed in Part IV.

Table 3.1. Velocity Measurements Through Top of River Wall

Monolith No.	Station No.	Path Length, ft	Velocity, fps	Signal Strength
35	3+48	7.8	11,590	Fair
	53	7.8	14,235	Excellent
	58	7.8	14,080	Good
	63	7.8	13,520	Fair
	68	7.8	12,665	Fair
36	83	7.8	13,780	Excellent
	88	7.8	13,780	Excellent
37	98	7.8	9,580	Poor
	4+03	7.8	13,380	Excellent
	08	7.8	13,290	Fair
38	18	7.8	14,310	Excellent
	23	7.8	14,580	Excellent
39	37	14.9	12,790	Excellent
	41	19.3	8,502	Poor
	69	23.0	NR*	
40	76	8.0	14,060	Good
	81	8.0	12,620	Good
	86	8.0	12,250	Good
	91	8.0	10,945	Good
41	96	(Spalled)		
	5+01	8.0	8,130	Poor
	06	8.0	10,050	Good
	11	8.0	8,430	Fair
42	16	8.0	11,730	Good
	21	8.0	13,200	Good
	26	8.0	13,245	Excellent
	31	8.0	12,140	Good
43	36	8.0	8,735	Poor
	41	8.0	10,460	Good
	46	8.0	13,535	Excellent
	51	8.0	13,535	Excellent
44	56	8.0	13,700	Excellent
	61	8.0	14,310	Excellent
	66	8.0	13,935	Excellent
	71	8.0	13,650	Excellent

(Continued)

Table 3.1. (Concluded)

Monolith No.	Station No.	Path Length, ft	Velocity, fps	Signal Strength
45	76	8.0	11,545	Poor
	81	8.0	9,915	Poor
	86	8.0	11,445	Good
	91	8.0	12,325	Good
46	5+96	8.0	10,365	Fair
	6+01	8.0	10,150	Fair
	06	8.0	13,010	Excellent
47	13	9.8	12,250	Fair
	17	13.8	7,190	Poor
	35	22.6	NR	
48	69	22.6	NR	
	75	22.6	NR	
49	85	18.3	7,135	Poor
	91	13.0	10,935	Poor
	99	7.9	12,740	Good
	7+05	7.9	12,825	
50	12	7.9	10,435	Fair
	17	7.9	10,895	Fair
	22	7.9	7,900	Poor
	27	7.9	12,210	Good
51	32	7.9	13,810	Excellent
	37	7.9	13,415	Good
	42	7.9	12,420	Good
	47	7.9	13,080	Good
52	7+54	7.9	13,550	Good
	57	7.9	13,550	Good
	62	7.9	13,620	Good
	68	7.9	12,620	Fair
53	72	7.9	12,500	Good
	77	7.9	12,865	Excellent
	87	7.9	13,015	Excellent
54	97	11.0	12,645	Good
	8+02	16.3	15,235	Good

Table 3.2 Land Wall Velocity Measurements

Location No.	Velocity, fps	Signal Strength
1	14,165	Good
2	14,835	Excel
3	13,775	Good
4	14,795	Excel
5	14,005	Excel
6	13,625	Good
7	14,750	Good
8	14,325	Excel
9	13,625	Good
10	14,620	Excel
11	14,205	Good
12	14,205	Good

Note: All path lengths are 5 ft.

Table 3.3 River Wall Velocity Measurements

Location No.	Velocity, fps	Signal Strength
1	14,085	Good
2	14,705	Excel
3	14,085	Good
4	13,515	Good
5	14,325	Good
6	13,265	Fair
7	13,735	Good
8	14,450	Excel
9	13,625	Excel
10	13,055	Good
11	13,440	Excel
12	14,495	Excel

Note: All path lengths are 5 ft.

PART IV: DEFICIENCIES OR CONSIDERATIONS, REPAIR EFFORTS, AND PHASE II INVESTIGATION NEEDS

54. The factors being considered in this part can best be presented in tabular form and are given in Table 4.1.

55. The first repair effort at Troy Lock and Dam should be the sealing of construction joints. If the deteriorated surface concrete is repaired first, the sealing of the construction joints may damage some of the repaired surface. After the construction joints have been sealed, the deteriorated concrete surface can be repaired. The above sequence of repair is not essential but will be more effective and will produce a neater job.

56. The suggested procedure for preventing construction joint leakage by use of asphalt sealer is as follows:

- a. Caulk the joint to stop the water flow.
- b. Bore a 4- to 6-in. vertical hole into the construction joint as close as possible to where the water enters and penetrate 5 ft into the foundation.
- c. Dry the drilled hole surface as much as possible.
- d. Fill the hole with asphalt sealer.

57. The final part of the Phase II project should be a feasibility study for rehabilitation or replacement of the lock and dam. At this time it seems that rehabilitation will be the effort which is needed.

Table 4.1. Deficiencies or Considerations, Repair Efforts, and Phase II Investigation Needs

Structure Being Considered	Deficiencies or Consideration	Repair Efforts	Phase II Investigation Needs
Lock	1. Concrete cracking	Seal the concrete cracks in the monoliths where the water gushes upward from behind the land wall with quick-setting, shrinkage-compensating portland cement grout.	None
	2. Construction joint leakage	Seal behind land wall with a. Chemical grout. b. Portland cement grout. c. Compaction grouting as determined by field tests of cores from the backfill material.	
		Seal the construction joints in the river wall and river face of the land wall with chemical grout by drilling vertical holes in the construction joints close as possible to the entry of water into the joint and pack the hole with asphalt sealer (see suggested procedure given in the first of this chapter).	Take four cores of backfill material
	3. Porous land walls	Seal behind land wall with a. Chemical grout, b. Portland cement grout, or c. Compaction grouting as determined by field tests of cores from the backfill material.	Same as for deficiency No. 2

(Continued)

Table 4.1. (Continued)

Structure Being Considered	Deficiencies or Consideration	Repair Efforts	Phase II Investigation Needs
	4. Deteriorated surface concrete	Repair, specifics to be determined in Phase II work.	Core to determine depth of deteriorated concrete and for selected samples perform petrographic analysis, examination for deteriorating agents and material property determination. Determine and report the most efficient and economical repair procedure.
	5. Undercutting at level of main tidal fluctuation in base of main control house and in river wall monoliths.	Repair, specifics to be determined in Phase II work.	Same as for deficiency No. 4.
	6. Undercutting of concrete at filling and emptying ports.	Repair, specifics to be determined in Phase II work.	Same as for deficiency No. 4.
	7. Concrete removal on the vertical wearing surface of guide guard, and lock wall.	After coring decide on: a. Replacement of specific depth of deteriorated concrete and placement of wall armor. b. Place protective wall armor on walls.	Same as for deficiency No. 4.

(Continued)

Table 4.1. (Continued)

Structure Being Considered	Deficiencies or Consideration	Repair Efforts	Phase II Investigation Needs
	8. Structural stability of walls.	To be determined.	Perform stabilities of typical monoliths to indicate their adequacy and to use the results as input to considerations when grouting behind the land wall.
Dam	9. Deteriorated construction joints.	Seal with chemical grout, quick-setting, shrinkage-compensating portland cement grout or by drilled holes packed with asphalt sealer.	None.
	10. Deteriorated surface concrete.	Prepare and epoxy the eroded surface.	Core to determine depth and extent of deterioration.
	11. Surface contact of dam monoliths with foundation.	To be determined.	Core to determine this contact.
	12. Vibration of dam monoliths.	To be determined.	Monitor the displacement amplitudes and period. Perform a structural analysis with these displacement records and evaluate this continual effect on the dam monoliths.
	13. Stability analysis.	To be determined.	Make four stability analyses.

(Continued)

Table 4.1. (Concluded)

Structure Being Considered	Deficiencies or Consideration	Repair Efforts	Phase II Investigation Needs
End pier at end of dam on powerhouse side of river.	14. Concrete cracking.	To be determined.	Structural analysis determining how ice loads can affect this cracked monolith. Determine needs for repair and operational procedures.
	15. Construction joints.	Seal with epoxy grout.	None
Gated section.	16. Concrete cracking.	Seal with epoxy grout. Get a light but removable handrail for top of pier.	None
	17. Concrete deterioration.	Repair, specific to be determined in Phase II work.	Same as for deficiency No. 4.

PART V: CONCLUSIONS

58. Initial observations of Troy Lock and Dam give worse impressions of structural deficiencies than are actually the case. The Phase I study reveals that the interior concrete of the lock is sound and of sufficient strength. The concrete cracking of the lock is negligible and is insignificant in the dam and gated spillway except for:

- a. The pier where the access to the dam tunnel on the powerhouse side of the river is located.
- b. The piers of the gated section.

59. Troy Lock and Dam is in the advanced stages of surface concrete and construction joint deterioration and this must be repaired.

60. Assuming that the structural evaluations for the Phase II study show no serious deficiencies and the concerns for concrete cracking in the dam and gated spillway can effectively be repaired and preventive measures implemented, the lock, dam, and gated spillway are structurally adequate. At this stage of the study, all conditions have not been evaluated such that feasible repairability is certain, but the Phase I study indicates that feasible repair is highly probable if the deficiencies listed in Part IV can be economically corrected.

PART VI: RECOMMENDATIONS

61. It is recommended that concrete cores be obtained to determine the depth of concrete deterioration in the lock and selected samples be used for:

- a. Petrographic analysis.
- b. Examination for deteriorating agents.
- c. Material property determination.

After the above data have been obtained, the most efficient and economical repair procedures should be determined and suggested.

62. Typical monoliths of the lock wall should be analyzed for stability to evaluate their design in relation to present-day criteria and to serve as a guide in assuming their safety when grouting is accomplished behind the land wall.

63. Cores should be obtained from the backfill material to evaluate necessary grouting and to determine backfill material properties for stability analysis.

64. The vibration amplitude and period of the dam monoliths should be monitored and a structural analysis performed with this data as input to evaluate the effect of the vibrations on the dam monoliths. The present condition of the dam monoliths must be known for this evaluation to take place; therefore cores should be taken to determine the extent of deterioration and the contact of the dam monoliths with the foundation. The concrete cores should be used for:

- a. Petrographic analysis.
- b. Examination for deteriorating agents.
- c. Material property determination.

Material properties should also be determined for selected cores from the foundation.

65. Stability analysis should be performed on four of the dam monoliths to evaluate them in relation to present-day criteria. A structural analysis should be made of the monolith containing the shaft which allows access to the dam tunnel from the powerhouse side of the

river. The structural analysis should be performed to determine how ice loads can affect this cracked monolith and to determine the needs for repair and/or specific needs in operating procedures.

66. A study should then be made to evaluate the feasibility of repair or replacement of Troy Lock and Dam.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Pace, Carl E

Engineering condition survey and evaluation of Troy Lock and Dam, Hudson River, New York; Report 1: Engineering condition survey / by Carl E. Pace. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

80 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; C-78-6, Report 1)

Prepared for U. S. Army Engineer District, New York, New York, N. Y.

1. Dam stability. 2. Engineering condition surveys. 3. Hudson River. 4. Locks (Waterways). 5. Troy Lock and Dam. I. United States. Army. Corps of Engineers. New York District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; C-78-6, Report 1.

TA7.W34m no.C-78-6 Report 1